SCIENCE

FRIDAY, APRIL 14, 1911

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THE ORIGIN OF THE THERMAL WATERS IN THE YELLOWSTONE NATIONAL PARK[1]

INTRODUCTION

FROM the earliest days of systematic geological research thermal springs have been a frequent subject of investigations by students of natural phenomena. From time to time numerous contributions to scientific literature bearing upon the nature of hot springs, partly descriptive and in part theoretical, have been presented to learned societies. Nearly all regions where such waters issue from the ground on an imposing scale appear to have been at one time or another scenes of eruptive energy. In so many instances has this been shown to be the case that thermal activity and volcanic manifestation have come to be regarded as associated phenomena. It by no means follows, however, that the original source of all these waters was, geologically speaking, deep-seated, and by a large school of geologists it has never been so regarded. In recent years the results of several suggestive researches have been published, in which the position is taken that superheated waters from igneous rocks are primitive in their origin; that is to say, they are derived from great depths in the earth's crust and are brought to the surface for the first time by volcanic forces.

The Yellowstone National Park affords one of the most remarkable, and probably one of the most instructive areas of thermal springs and geysers to be found in the world. The varied phenomena of boiling springs and aqueous vapors there stand unsurpassed. Several years ago, after a

[1] Annual address of the president, before the Geological Society of America, December 27, 1910.

study of the region under the auspices of the United States Geological Survey, I published in official documents, and later in Johnson's "Universal Cyclopædia," an article entitled "Thermal Springs," in which I stated the conclusion that the waters of these hot springs and geysers were essentially meteoric waters that had penetrated downwards a sufficient distance to attain an increased temperature, only to be forced again to the surface by ascending currents.

I propose on this occasion to present briefly some of the geological evidence on which these conclusions are founded. They are based on the nature and structure of the rocks through which the heated waters reach the surface, the mineral constituents contained in the waters, the composition of the associated gases, and the characters of the varied sediments and incrustations deposited around the springs and pools.

EOCENE IGNEOUS ROCKS

To understand correctly the relations of the thermal waters found in the park to existing geological conditions, a brief history of the salient features of its igneous rocks and their sequence seems necessary. The country included within the Yellowstone Park, the Absaroka Range, and the Wind River Plateau, consists essentially of masses of igneous rocks covering an area of over 5,000 square miles in the center of a continent whose three great rivers, the Mississippi, the Colorado, and the Columbia, here find their source. Within this region, through that vast period of time from the close of the Archæan to the dawn of the Tertiary, all evidences of eruptive energy are wanting. Coincident with the earliest indications of the post-Laramie orogenic movement came a period of intrusion which began in late Cretaceous time and continued with only slight periods of rest till near the end of the Pliocene. Whatever the primary causes were that produced this orogenic movement, the enlargement of the continental area, and the final withdrawal of the sea, they brought about mountain uplifts, crustal displacements, and volcanic activities of the first magnitude. The close of the Cretaceous in this part of the northern Cordillera was marked by the most profound stratigraphic break since Algonkian time. The oldest intrusives, recognized as such, are found in the northwestern corner of the Yellowstone park in what is now the Gallatin Range, and inaugurated a physical revolution. These rocks were forced in as sills between upper Mesozoic sandstones before the latter were much disturbed, as they lie unconformably interbedded between sediments which later were affected by the dynamic processes of mountain elevation. In this sense these earliest intrusions must be considered, structurally at least, as of Cretaceous age. They were succeeded by more powerful injections, accompanied by slow and protracted elevation of the Gallatin Range. With the emergence of land surfaces erosion followed and sediments were deposited unconformably. Elevation of mountain masses produced new physiographic features, and as a consequence changes in climatic conditions and modifications of living species, both animal and vegetable. The Tertiary period was ushered in. With the progressive building up of the range and the associated folding and compression of strata, viscous magmas were injected from unknown depths. Massive bodies were forced upward to definite levels, when, being unable to rise higher, they spread out laterally between strata of all ages from the Cambrian to the Laramie. Centers of powerful intrusion shifted from one locality to another, and within the confined limits of the range batholiths of no

mean proportions were forced upward. Evidence is wanting to show that any of these magmas in their upward movement ever penetrated to the surface; apparently they came to a standstill far below a covering of overlying sediments whose thickness must, for the present at least, remain a matter of conjecture. Excessive erosion since early Eocene time has laid bare these massive batholithic forms which now stand out as dominant features in the landscape.

There is no evidence to warrant the opinion that these porphyries and crystalline rocks were ever connected with vents discharging lavas, though there is, beyond the boundaries of the Gallatin Range, extravasated material of Eocene age covering large tracts of country. In the northeast corner of the park such surface flows are well developed in the accumulation of silts and ashes. Much of this material was laid down under relatively quiet conditions. Apparently they are much later than the crystalline rocks already referred to, but their age is determined by a characteristic flora corresponding with the well-known Fort Union beds of Montana of Eocene age.

In these extravasated lavas the influence of volcanic waters may be recognized in many ways, but degradation of the mass has been so great that evidence of individual extinct hot springs is no longer traceable; moreover, it would seem impossible to distinguish them from those belonging to Miocene eruptions.

MIOCENE IGNEOUS ROCKS AND THERMAL WATERS

The Absaroka Range shuts in the park plateau along its eastern border. Strictly speaking, it is not a mountain range, but rather a rugged, deeply dissected tableland, rising from 3,000 to 4,000 feet above the general level of the park. It stretches for eighty miles in a north-and-south direction and measures nearly fifty miles in width. In strong contrast to the Eocene igneous rocks this elevated tableland was steadily built up by tumultuous accumulations of breccias, agglomerates, silts and muds, the products of violent explosive action through numerous conduits from sources now concealed beneath the overlying load. Nearly all phenomena of ejected lavas seen in extinct volcanic areas elsewhere may be observed here. Finally, the mass was penetrated by batholithic intrusions, accompanied by innumerable dikes and sills, offshoots from the parent stock. All this was the result of long-continued, protracted energy, as clearly shown both by geological processes and the many successive fossil forests. These flourished through thousands of feet of eruptive material and were alternately killed by hot fragmentary lavas and preserved by renewed streams of muds and ashes.[2] The luxuriant vegetation which developed throughout this period is regarded by all paleobotanists as of Miocene age. All volcanic activity long since ceased.

What concerns us most at the present time is the influence of thermal waters derived from deep-seated sub-crustal sources upon both the volcanic ejectamenta and crystalline intrusives. The action of these heated waters may be observed equally well on what were surface flows and on the deeply buried intrusive masses. Such surface action may be detected at a number of localities by the presence of alteration products and traces of sediments, although in most cases the latter have been removed by running water. Underground action of sub-crustal waters is shown in many

[2] Arnold Hague, "Early Tertiary Volcanoes of the Absaroka Range," presidential address, Geol. Soc. of Wash., 1899, SCIENCE, March 24, 1899.

places from one end of the range to the other by deposits laid down from ascending igneous emanations in the form of aqueous and gaseous vapors charged with mineral matter. Such deposits consist essentially of quartz, galena, and copper minerals, carrying both gold and silver. They lie as contact products along the apophyses of the massive intrusions and never occur far away from them. They were deposited after the crystalline intrusives came to a state of rest, but probably long before they were chilled. It may not be necessary to add, but it should be borne in mind, that at the time of deposition they were much farther below the surface than they are found to-day. Mining companies have exploited the ores by shifts and tunnels, but so far as I know, such ore bodies have never proved lucrative, owing to their uncertainty and lack of continuity. Similar ore bodies in the mining regions of Montana and Colorado have been described by Emmons, Lindgren, Weed, Kemp, and others.

Another feature of these intrusive rocks of the Absarokas is seen in the narrow rifts and shrinkage cracks filled with quartz by the ascending currents from deep-seated sources. In like manner the cavities and druses found in the petrified trees of the fossil forests are lined with quartz crystals, due to heated siliceous waters coming up from below. To-day there are no hot springs or steam vents to be found in the Absarokas, save in a feeble way on the western flanks, where the ancient breccias have been penetrated by much later rhyolites.

It has seemed necessary to present this somewhat lengthy description of volcanic forces existing in Miocene time in order to bring out in strong contrast the conditions prevailing during Pliocene and recent times.

PLIOCENE IGNEOUS ROCKS AND THERMAL WATERS

After the pouring out of the basic breccias and lavas of the Miocene, volcanic energy, for a time at least, ceased. Atmospheric agencies removed a large body of the surface rocks and carved out drainage channels in the easily disintegrated material. Following a prolonged interval of comparative rest came renewed activity, with marked changes in the nature of the eruptive lavas. Vast masses of rhyolite were extruded, not upon preexisting mountains, but over an enclosed basin, converting it into a rugged tableland and submerging the flanks of the bordering ranges. This sharply defined region has been designated as the Park Plateau. It embraces a tract of country fifty by forty miles, including approximately 2,000 square miles. Strictly speaking, it is not a plateau in the general acceptation of the word, but presents a broken surface accentuated by bold escarpments and abrupt slopes of lava flows. While the topography of the tableland has, to some extent, been modified since Pleistocene time and trenched by ice action, giving the effect of individual plateau blocks, the mass can not be considered otherwise than as a geological unit. The earliest rhyolitic eruptions spread over a very uneven surface, the structural features of which may be fairly well inferred from exposures of sedimentary rocks rising through the surrounding lavas or cropping out from beneath the outer boundaries of the plateau. The rhyolite also lies unconformably upon the eroded surfaces of basic breccias, and not infrequently occupies the older valley bottoms, clearly showing the much later age of the siliceous lavas. Although sharply defined by topographic relief and geological sequence, both periods of ejection are still more strongly contrasted by marked dif-

ferences in the phases of eruption which built up the two volcanic regions.

On the rhyolite plateau there are no evidences of violent explosive action. The complete absence of true volcanic breccias is a significant feature of these later flows. Dikes, veins and horizontal sills, together with nearly all the phenomena of deep-seated intrusions, are wanting. The rhyolite shows scarcely any indications of hydrothermal activity during eruption. In the abrupt escarpments made up of successive sheets there are no signs of surface flows having been exposed to long-continued atmospheric agencies, no wind-strewn ashes or any vestiges of vegetation. On the contrary, everything clearly indicates a relatively rapid accumulation of viscous masses from the beginning to the end of the rhyolite period. What impresses one most is the absence of stages of activity with intervals of quiescence, there being rather a series of massive eruptions piled up one upon another. In the central portion of the park the rhyolites have a maximum thickness of 2,000 feet, and over large areas they may be assumed to measure 1,500 feet.

Subsequent to the rhyolites and the building up of the park plateau came a few dikes and thin sheets of basalt. They are the most easterly occurrence of those broad basaltic flows that spread over southern Idaho and the Snake River plain. In the park country they are of Pliocene age, that is to say, they are older than the glacial ice. They make the final chapter in the history of Tertiary igneous rocks. As they play no recognized part in the problems bearing upon thermal waters they may be dismissed at the present time with this brief mention.

Unquestionably the Pleistocene age, with its changed conditions, set in not long after the dying out of rhyolitic eruptions, as is shown by the relatively slight erosion of the plateau and the beginning of canyon sculpturing. All geological evidence tends to prove that the rhyolites belong to the Pliocene age.

DURATION OF THERMAL ACTIVITY

That the activity of thermal waters was approximately coincident with the cessation of rhyolite ejections is, fortunately, clearly proved by the massive horizontal beds of calcium carbonate laid down on the summit of Terrace Mountain, where they attain a maximum thickness of nearly 250 feet, although the average is much less. Without doubt they are the oldest deposits of travertine in the region of Mammoth Hot Springs, and rest directly upon fresh, unaltered rhyolite. Glacial ice from the Gallatin Mountains moving eastward occupied the intervening Swan Lake Valley and passed over the top of Terrace Mountain on its way to the broad, open valley of the Yellowstone. On the recession of the glacier fragments of crystalline rocks, undoubtedly brought down from the Gallatin country, were left strewn over the travertine of Terrace Mountain.

It is a fair assumption that if these thermal waters were issuing through rhyolite at one locality in pre-glacial time, similar hot waters and gaseous emanations should have reached the surface at other points on the plateau. If any such remnants of sinters still remain it seems impossible, from our present knowledge, to discriminate between them and those of post-glacial time. Erosion has carried away not only every trace of these earlier deposits, but has removed nearly all evidences of pre-glacial rock decomposition. Modifications in topographical relief fail to indicate two distinct periods, owing probably to the relatively slight deposition of sinter before the ice.

Following the withdrawal of a broad ice sheet, ascending heated waters, acting with renewed energy upon the walls of innumerable fissures and rifts, bleached and kaolinized massive blocks of rock. This decomposition of plateau lavas proceeded on a grand scale and left an indelible impression upon the rhyolite areas. In regard to the age of the hot springs it is reasonable to conclude that thermal waters were as active at the close of the rhyolite extrusions as at any subsequent period. The antiquity of many localities of decomposed rhyolite is clearly evident, as shown by post-glacial sculpturing. In certain areas where hydrothermal energy was formerly a long-continued process, evidence of the presence of such sources of heat have long since ceased. No one who has studied the gradual development of these decompositions and metasomatic changes under the influence of acid solfataras, or the deposition of sinter now taking place from alkaline siliceous waters, can doubt the lapse of time required by these geological agents to accomplish the results observed. Such processes can not, however, differ essentially other than in degree from those observed to-day. In my opinion, they have never ceased to be active and have only varied in intensity from time to time. It meets all the requirements, therefore, for our present purpose, to consider the phenomena now taking place or since the hot springs and geysers were first brought to the attention of the scientific world, about forty years ago.

CLIMATIC CONDITIONS

Precipitation of moisture over the plateau and encircling mountains is far heavier than that taking place over the semi-arid regions below. Not only is the rainfall higher for every month of the year, but the temperature is correspondingly lower. Four large rivers, the Yellowstone, Snake, Madison, and Gallatin, carry the waters from the uplands to the lowlands. Knowing the amount of water leaving the park by these principal drainage channels, it is easy to estimate approximately the total amount of surface waters carried away.

Meteorological records, more or less complete, have been kept at Mammoth Hot Springs for over a quarter of a century, and during one winter at the Firehole Basin. From these data an approximate estimate can be made of the water falling over the entire region. Some years ago instrumental measurements were undertaken during the summer to determine the amount of evaporation on the open sinter plain in the Upper Geyser Basin. Similar observations were made at the outlet of Yellowstone Lake. Taking into consideration the annual precipitation and run-off, and the summer evaporation, I believe the supply of water greatly exceeds the amount carried away by surface streams. Climatic conditions, as they exist in the park to-day, favor forest development and a varied undergrowth. It is estimated that over 82 per cent. of the region is forest-covered. For eight months precipitation occurs in the form of snow, which, protected by the forests from the sun's rays and the drying winds, melts slowly and lingers on well into midsummer. On the adjoining mountains the snow seldom entirely disappears. The retention of the water by forest and undergrowth brings about the development of the many meadows, marshes and bogs. Scattered over the tableland occur frequent ponds and lakelets, carrying in the aggregate a very considerable body of water. In this connection may be mentioned such large reservoirs as Yellowstone Lake, covering over 125 square miles of surface, and Sho-

shone Lake, measuring 12 square miles, to say nothing of other picturesque sheets of water of less imposing dimensions, all of which lie upon the rhyolite from 500 to 700 feet above the Upper Geyser Basin, where the greatest number of large geysers is found and the activity and overflow of thermal waters displayed on a grand scale. In time, much of the water from the meadows and ponds naturally finds its way to surface streams. Another portion is taken up by the luxuriant vegetation or is absorbed by the atmosphere. The remaining water, which constitutes a very considerable volume, is drawn down through openings into underground reservoirs. In other words, these descending waters slowly percolate through the viscous lavas.

PHYSICAL STRUCTURE OF RHYOLITES

Returning for a few brief moments to rhyolite flows, let us consider certain physical features due to textural modifications. No region surpasses the Yellowstone Park in the varied phenomena of highly acid extrusions. This is especially true of the more glassy types, and in general a glassy ground mass characterizes most of these lava sheets. Mr. J. P. Iddings has submitted a large series of specimens of the park rhyolites to a searching petrographical investigation, making a special study of the microgranular structure, and the relations of the different microstructures to one another, and pointing out the abrupt transitions from the glassy to the crystalline and from the pumiceous to lithoidal forms. For further details the student is referred to this admirable work. In conclusion, Mr. Iddings calls attention to the agency of water in bringing about the varied products. He says:

> The heterogeneity of the acid lavas so far as known is confined to the distribution of vapors, presumably of water, and suggests that the water thus irregularly disseminated has not existed within the magma long enough to become uniformly diffused. It must therefore be looked upon as water absorbed near the earth's surface.[3]

From the point of view of the present discussion the cause of these remarkable structural variations concerns us less than the influence exerted by such textural modifications in the creation of fissures, fractures and capillary openings for the percolation of waters. Obsidians, perlites, and pitch-stones were poured out over the greater part of the central plateau and may be found at the base of bold escarpments, under accumulation of successive flows. Glassy forms present as marked a feature of many of these earlier outpourings as they do of the more recent flows. They were surface flows when ejected. They prove conclusively, on geological evidence, that similar physical conditions were identical from the beginning to the close of the rhyolite phase of eruption. The liquidity of the magma and its crystallization changed from time to time, being dependent upon varying causes, such as the degree of temperature when ejected from the point of discharge, the volume of the mass, and the power of the lava to hold its contained heat.

Banded and laminated lavas, contact surfaces between magmas of different physical properties, shrinkage cracks and jointings in obsidian and perlite, overlapping of lava flows, all caused numerous narrow capillary spaces in the rock. Some of these openings for short distances lie parallel with the lava flows; others are vertical along planes of jointing, while still others indicate great irregularity, broadening and contracting along a circuitous course. Uniting below the surface, they develop into wider channels, affording free circu-

[3] J. P. Iddings, "Geology of the Yellowstone National Park," Mon. XXXII., Part II., p. 425.

lation of either descending or ascending waters.

MINERAL AND CHEMICAL COMPOSITION OF RHYOLITE

As I hope to be able to show that the mineral matter brought to the surface in solution by ascending thermal waters circulating through rhyolite is mainly derived from these lavas, it is necessary to examine in detail both their chemical and mineral composition. The chemical composition of the rhyolite appears remarkably uniform when the enormous bulk is considered and the different physical conditions under which the lava streams were extravasated.

In the subjoined table will be found analyses of eleven specimens of rhyolite, arranged according to their tenure of silica. They were made in the laboratory of the United States Geological Survey, but are here brought together in tabular form.

ANALYSES OF RHYOLITES FROM YELLOWSTONE NATIONAL PARK

	SiO_2	TiO_2	Al_2O_3	Fe_2O_3	FeO	MnO	MgO	CaO	Na_2O	K_2O	Li_2O	P_2O_5	SO_3	H_2O	Cl	Total
I. Upper Geyser Basin	70.92	.16	13 24	3 54	.66	.14	.23	1.42	4.28	4.25	—	.18	—	.57	—	99.59
II. Head of Tower Creek	71.85	.43	13.17	2.17	1.34	.12	.63	2.25	4.06	3.89	—	.14	—	.43	—	100.48
III. Plateau east of Willow Park	72.59	.52	13.47	1.58	1.32	Trace	1.05	2.12	4.63	2.52	—	None	—	.18	—	99.98
IV. Cliff east of Excelsior Geyser	73.84	—	12.47	.32	.90	Trace	.25	1.08	2.88	5.38	—	—	—	2.76	—	99.88
V. Obsidian Cliff	74.70	None	13.72	1.01	.62	Trace	.14	.78	3.90	4.02	—	None	—	.62	.40	100.31
VI. North Madison Plateau	75.19	None	13 77	.61	1.37	Trace	.09	.68	3.83	3.33	.02	None	.29	.65	—	99.83
VII. Elephants Back	75.34	None	12.51	.42	1.55	.07	.32	1.07	3.31	4.17	Trace	None	.42	.86	—	100.04
VIII. Obsidian Cliff	75.50	None	13.25	1.02	.91	None	.07	.90	4.76	2.85	.06	None	.32	.41	—	100.05
IX. Obsidian Cliff	75.52	None	14.11	1.74	.08	None	.10	.78	3.92	3.63	—	None	—	.39	.11	100.49
X. Sheridan Volcano	75.89	.50	12.27	1.12	1.37	None	.29	.86	3.23	3.42	.01	None	.28	.82	—	100.06
XI. Sherman Volcano	77.65	.14	11.50	1.21	.26	None	—	.59	3.33	4.85	—	.02	—	.28	—	99.84

In five analyses the range in silica falls within seven tenths of a per cent. Lime and magnesia show the greatest variation, while the alkalies do not appear to be higher than in many other localities where rhyolite has been extravasated in the form of massive eruptions. Titanic oxide has been determined in small amounts, but was not detected in the obsidians or in any of the extreme glassy rocks. On the other hand, both sulphuric acid and chlorine occur in small quantities in the fresh glassy varieties, but, curiously, analysis fails to show the presence of both in the same flow. Traces of manganese have been detected in many specimens from widely separated parts of the tableland, which is interesting from the fact that in one or two localities solfataras have deposited manganese oxide as dendritic incrustations. Considering the rhyolite as a homogeneous mass the composition of the molten magma is probably best shown in the specimen from Madison Canyon. Here the silica percentage was 75.2 per cent., the alumina 13.77, and the combined potash and soda 7.16.

As regards mineral composition the rhyolite is by no means as simple; owing to textural modifications that range from semitransparent, amorphous obsidian, to liparite with relatively little ground mass. Nevertheless, the species that have crystallized out from the magma are few in number, the only essential rock-making minerals being quartz and sanidine. In certain lavas quartz, in irregular crystals, occurs abundantly disseminated as megascopic phenocrysts while in others it is wholly wanting. Plagioclase stands next in order, being easily recognized in many thin sections under the microscope, although being seldom recognized by the naked eye. This is probably owing to the small amount of alkaline earths present. Small flakes of biotite have been detected here and there, but in the typical rhyolite

it may be said to be absent. Pyroxenic minerals are rare and only in microscopic crystals. Magnetite is somewhat more widely distributed, but only in minute grains, as might be supposed from the low percentage of iron oxides. The presence of titanium in the magma reveals itself in the disseminated grains of ilmenite and pseudobrookite. Apatite, zircon, and allanite complete the limited list of accessory minerals.

CLASSIFICATION AND COMPOSITION OF THERMAL SPRINGS

The number of springs scattered over the park, from which flow varying amounts of thermal waters, probably exceed twenty-five hundred. If to these be added the fumaroles, solfataras, and narrow rifts from which issue steam and gaseous emanations mingled with more or less water, the number would be greatly augmented. It is impossible to enumerate them, as new ones are frequently reaching the surface, while others are slowly becoming extinct. Furthermore, it would be no easy task to decide whether single points of discharge should be counted, or considered as a group having a common source a short distance below ground. These thermal waters reach the surface holding mineral matter in solution, derived from the decomposition of rocks through which they pass in their upward movement. They may be arranged under four heads: (1) waters carrying calcic carbonate in solution, (2) siliceous alkaline waters rich in dissolved silica, (3) calcic siliceous waters having both properties of calcic carbonate and siliceous alkaline springs, (4) siliceous acid waters, usually holding free acid in solution.

Nearly thirty of these thermal waters have been analyzed by F. E. Gooch and J. E. Whitfield in the laboratory of the United States Geological Survey and the results published in a separate bulletin.[4]

Among these waters are several from the Mammoth Hot Springs characterized by the large amount of calcic carbonate in solution, associated with free carbon dioxide and sulphates of magnesium and the alkalies. Underground conditions were doubtless favorable for holding in solution large amounts of calcic carbonate. With the relief of pressure at the surface and the diffusion of free carbon dioxide, precipitation followed, as shown in the deposits which have made the Mammoth Hot Springs so famous. From the present point of view we are not so much concerned with depositions from these waters as with the waters themselves and their geological relations, since they unquestionably have a common source with those of the rhyolite plateau.

At the Mammoth Hot Springs the upper lava flows lie directly against inclined Jurassic limestones. The circulating hot waters having been diverted in their course, traverse the limestone before issuing at the surface. Apparently the waters derive a large part of their mineral constituents from the limestone. In contrast to the hot waters of the plateaus they carry but little silica in solution. Far to the southward, where the rhyolite tableland ends, the attenuated lava streams also rest against uplifted limestones. Calcic carbonate springs, although of modest dimension, issue through the rhyolite, but have derived their mineral contents mainly from the adjacent limestones. Both the carbonated waters and the travertine deposits resemble those at Mammoth Hot Springs. Similar geological relations may be observed near the eastern

[4] F. A. Gooch and J. E. Whitfield, "Analyses of Waters of Yellowstone National Park," Bull. U. S. Geol. Survey No. 47, Washington.

limits of the rhyolite at Soda Butte Spring, and again near the western border.

On the other hand, wherever the heated waters issue from the rhyolite of the tableland they are characterized by a high percentage of silica. These waters occur distributed over a wide area and furnish the great volume of water discharged from the geysers and hot springs, and for this reason have excited more general interest than the smaller springs. They have supplied the silica for the many square miles of glittering white sinter plains. For the most part they are siliceous alkaline waters, as in the Upper Geyser Basin and the Firehole Basin. They may, however, be slightly acid or neutral, as in the case of many of them in Norris Basin.

The silica occurs in solution as hydrated silica associated with carbonates and chlorides of the alkalies, together with small quantities of sulphates. Arsenic and boron have been determined in nearly all geyser waters, probably combined with soda as arsenates and borates. Traces of bromine, phosphoric acid, soda, manganese, lithium, cæsium and rubidium were detected in several instances, but lithium and bromine are the only elements present in sufficient quantities to allow of estimation. Tests were made for titanic acid, nitric acid, iodine, fluorine, barium, and strontium, but none of them were found. Special examinations were made in concentrated solution for tin, copper, and lead, but no one of them was present. In this connection it may be pointed out that while veins carrying lead, copper, and silver are found associated with Eocene and Miocene igneous rocks, these metals have never been detected in either the rhyolite or waters of the park.

A study of these chemical analyses brings out clearly the marked differences in percentages of substances held in solution, especially silica, even in adjoining geysers. This holds equally well for the siliceous alkaline waters from the same geyser basin as from those collected from different localities. Waters examined the same year show as great variations as those collected one or two years apart. The silica, as determined by analysis, ranges from .22 to .67 gram per kilogram of water, the former being the amount found in the cauldron of the Excelsior, having the largest outflow of any pool in the park, and the latter from Opal Spring in Norris Basin, with but slight run-off, and without any apparent inflow. The cause of these differences is, I believe, to be sought in the varying amounts of infiltrating surface water.

Dr. W. H. Hallock has shown conclusively, by experimental tests with self-registering thermometers, that the thermal waters stored in underground geyser reservoirs possess a temperature far in excess of the boiling point at the surface, due to increased pressure of the overlying column of water in the geyser tube. The results were in accord with the theoretical boiling point. It can not be affirmed positively that these superheated waters maintain the same composition after being thrown out as the underground waters at greater or less depth or even with those of the geyser reservoirs. On the other hand, there exists no evidence of chemical changes due to relief of pressure before the waters reach the surface through geyser orifices.

Upon the relief of pressure, hydrated silica, associated with traces of an equally insoluble silicate of alumina and lime, is deposited upon the broad plains of the geyser basins. Nearly all remaining constituents are carried away in solution by surface streams. Although the composi-

tion of the deposited sediment is everywhere much the same, its external habit varies with the manner of its secretion, which may have happened in several ways. It may have been caused by precipitation on relief of pressure, precipitation on cooling, separation by evaporation, and assimilation by algæ. Mr. Walter H. Weed has shown conclusively the important part such organisms perform as geological agents in the accumulation of sinter deposits.[5]

The volume of siliceous alkaline waters far exceeds those of the acid type. On the other hand, the latter occur more widely distributed, are more complex in their composition, and consequently more varied in their deposits. These acid waters come to the surface through fumaroles, solfataras, and the so-called mud springs and paint pots. In nearly all such occurrences the waters carry either free hydrochloric or sulphuric acid. In general these thermal waters, which rise through narrow seams and rifts, run but little water and leave behind only thin incrustations around the sources of supply. These deposits are found widespread over the park and consist principally of sulphates of alumina and double compounds of alumina and iron. While they show a mingling of saline compounds carrying more or less silica as an impurity, the number of mineral species remains singularly few. Halotrichite, alunogen, and alum are the only minerals of the alum group determined. In the far more arid regions of New Mexico accumulations of these minerals have been described by Dr. C. W. Hayes[6] as deposits from aqueous solutions associated with igneous rocks.

Under quite different conditions, and as thin layers deposited below water level in the Norris Basin, occur incrustations of both sulphides of arsenic—orpiment and realgar. They are, however, very restricted in quantity. Scorodite, delicate crystals of sulphur, and ochreous deposits, mainly ferric oxide and silica, are characteristic of certain acid and neutral waters. These sediments and incrustations point clearly to different conditions of thermal activity. In strong contrast from those described in connection with siliceous alkaline waters they indicate an earlier stage in the development of rock decomposition.

GASES FROM THERMAL SPRINGS

Several years ago gases emitted from many of the springs were collected and submitted to analysis by Professor F. C. Phillips of Pittsburgh. They were all found to carry carbon dioxide, oxygen, hydrogen, and nitrogen, but to vary greatly in relative amounts. In general, those from Mammoth Hot Springs, where the waters issue through limestones, are characterized by carbon dioxide, one analysis from the spring upon the main terrace holding no less than 98.68 per cent. of the gas. Those from the upper basin, which issue directly from the rhyolite, consist principally of nitrogen; the Artemesia Geyser carrying 95.08 per cent. of the latter gas. Traces of methane were found in several waters. Hydrogen sulphide was only detected in two samples, and in neither of these did the gas amount to one per cent. of the gaseous content. One of these was from a sulphur spring in the Mammoth Hot Spring Basin, and the other from the Shoshone Geyser Basin. In none of the waters from the geysers and large hot

[5] Walter H. Weed, "Formation of Travertine and Siliceous Sinter by the Vegetation of Hot Springs," U. S. Geol. Survey, Ninth Ann. Rept., Washington, 1890.

[6] Dr. C. W. Hayes, Bull. U. S. Geol. Survey, No. 315, pp. 215–223, 1905.

springs in the three principal geyser basins was any hydrogen sulphide detected.

Professor Phillips says:

> There is, in fact, a curious gradation between analyses from No. 1 and No. 10, as regards the proportion of nitrogen and carbon dioxide. Oxygen is present in all of them, and as ten of these gases contain combustible elements, hydrogen and methane, it is evident that the gas as it escapes from the spring has not been exposed to a high temperature.

It is admitted by most authors that under certain conditions all these gases may be contained in surface waters. I think it has been shown that under the peculiar conditions in which these waters occur, and their lack of uniformity of composition, they must be considered as absorbed by vadose waters.

One of the most marked characteristics and one of geological significance is the frequent variation shown in temperature, flow, and salinity of the thermal waters where they issue from the rhyolite plateau. The solvent power of water holding mineral matter in solution is, as is well known, far greater than that of pure water. Now the downward percolating waters gather material from the disintegrated rhyolite soil and in some measure from the soluble salts previously brought up from below. There is also a certain amount of carbon dioxide derived from the atmosphere. It is a fair assumption, therefore, that in percolating downwards the waters carry with them to the water level below no inconsiderable amount of material.

The ascending superheated waters, under pressure, exert a far greater influence. The work done by these waters, and that which is still going on, is self-evident even to the most casual tourist. It is shown by the broad areas and ridges of altered and bleached rhyolite. Nowhere is this more in evidence than in the escarpments along the Grand Canyon of the Yellowstone, where the gorgeous coloring is due to the oxidation of the ferruginous minerals. The potent influence of such waters under existing conditions can hardly be questioned. They readily attack both the glassy groundmass and crystalline feldspars of the rhyolite, and when the metasomatic changes are complete they leave behind an impure kaolinized material mixed with quartz and held together by colloidal silica.

DEVELOPMENT OF SPRINGS AND GEYSERS

The ascending waters, in their circuitous course, penetrate fresh seams and cracks in unaltered rock which slowly widen under the disintegrating influences of aqueous vapors. Finally, the thermal waters, following these cracks, issue at the surface as hot springs and pools. The early waters are usually acid in composition, and deposit ferric and aluminous salts. Occasionally they set free sulphur, derived from the decomposition of hydrogen sulphide. In time the openings through which they flow become broader, the waters themselves, free from hydrogen sulphide, become clearer and neutral, and at last issue as siliceous alkaline waters. Underground reservoirs are excavated and become sources of hot springs, and, under favorable conditions, geysers. The geyser itself is simply a stage in the development of geological processes. In time geysers themselves become extinct. New geysers break out and, given the essential physical conditions, may develop eruptions quite as fine as any in action at the present time. Geologically speaking, the final stage of thermal activity is a hot spring. The tendency of a geyser is to develop a hot surface pool. If from such pools there is discharged a sufficient amount of overflow, and if from the surface of these geyser pools there is an ample dissipation of heat into the surrounding atmosphere, explosive

action may cease and the geyser, as such, may become extinct. It is frequently stated that some geyser has ceased to be active and that this indicates the slow dissipation of the original source of heat. This I believe to be an error. The change is simply due to a shifting of the channel of the ascending waters.

If, on the other hand, there should be marked climatic changes and arid conditions should set in over the park and adjoining mountains, in my opinion, thermal springs would become extinct. Should this happen it would be evident beyond all question that the waters were derived from vadose sources. Again, with the disintegration of lavas and the building up and enlargement of reservoirs, existing conditions of hydrostatic pressure would cease and the circulating waters, unable to rise, would distribute themselves laterally; in which case there might break out at the base of the rhyolite plateau calcic springs such as we now find and have already described.

In all probability the magnitude of a geyser is, in a measure, dependent upon the size of the underground reservoir or series of reservoirs, produced by the disintegration of lavas along channels of ascending waters. It has been demonstrated by self-registering thermometers that cool infiltrating waters may drain into partially erupted reservoirs after geyser eruption. This has been shown in the case of the Giantess Geyser. The question was once asked by an attendant at the hotel who had spent several summers in the park, why Old Faithful was more apt to be several minutes behind time in September than in July. I am not aware that such a condition was ever established, but if so, my reply would be that in the autumn the infiltration of surface waters is not as rapid as in early summer, hence a retarding of the eruption by several minutes.

It is probable that the Norris Geyser Basin, in its thermal development, is later than the Upper Geyser Basin. In the former are found the early and more acid conditions, the waters of the geysers are mainly neutral and form deposits of arsenical sulphides, alum, and ferric salts. These phenomena are for the most part absent in the Upper Geyser Basin, where the waters have reached a more advanced stage and possess a siliceous alkaline composition.

With the exception of arsenic and boron, which occur in minute quantities, all the elements brought to the surface in solution by the thermal waters of the park have been found in the rhyolite. In this connection it may be said, and it is generally accepted by those who have studied the region, that the mineral waters of Pfaeffers, in the Tyrol, have a vadose origin, and analyses show that both these elements are present.[7] Both these elements are found associated together in many thermal waters of Europe. Not only is it true that, with these exceptions, all the elements are accounted for in the rocks, but the proportion of the ingredients in the waters bears a remarkable relation to that of the elements in the rhyolite itself. Silica and the alkalies are the predominating elements. Even lithia, which is a feature of many siliceous lavas, has been quantitatively estimated in all these thermal waters. The water from Old Faithful yielded .0056 of a gram per kilogram of water, which, according to the theoretical composition, shows that lithium chloride forms 2.44 per cent. of the amount of material held in solution. The neighboring Giantess Geyser carried precisely the same amount of lithium chloride. The low percentage of iron, manganese, lime, and magnesia contained in the ascending waters is readily accounted for by the comparatively small

[7] M. De Launay, *Annales des Mines*, February, 1894.

quantities of these elements in the glassy rhyolite through which these waters pass.

The circulating ascending waters may, to some extent, be charged by foreign substances other than by superheated aqueous vapors. Nevertheless, in the park country the vadose ascending waters do not appear to have been greatly affected by any primitive, deep-seated waters or their contents. Even if foreign mineral matter were present, it does not follow that the material was not taken up originally by vadose waters.

In Iceland geological conditions are apparently quite different, and volcanic eruptions may be said, geologically speaking, to be still going on, in strong contrast to the Yellowstone Park, where such action ceased many thousand years ago. In Iceland the thermal waters are, in my opinion, mainly vadose, and their heat derived from sources not far below the surface.[8]

I agree with Dr. Rudolf Delkeskamp[9] that temperature, included gases, and salinity in many localities are not in themselves conclusive evidence of the source of thermal waters, and that far safer criteria for the determination of the primitive origin of waters are to be sought in uniformity of flow and chemical composition. What I wish to emphasize, however, is that the thermal waters of the Yellowstone National Park are characterized by frequent variations of temperature, progressive transitions in chemical composition, lack of uniformity in mode of occurrence, and shifting in points of discharge; in other words, they lack the essential characters of primitive waters derived from deep-seated sources.

[8] Since presenting this address I have received from Dr. Thorkell Thorkelsson, of Copenhagen, a copy of a suggestive paper on "The Hot Springs of Iceland" which confirms me in the opinion of the vadose origin of the Iceland thermal waters. Dr. Thorkell's paper appears as a recent publication forming one of the *Mémoires de l'Académie Royale des Sciences et des Lettres de Danemark*, Copenhague, 1910.

[9] "Juvenile und vadose quellen," *Balneologischen Zeitung*, XVI., Jahrgang, No. 5, 1905.

RADIOACTIVITY OF THERMAL WATERS

Throughout this paper in the discussion of the geological relations of the thermal waters to the rhyolite eruptions laboratory investigations bearing upon the composition of the rocks, waters, sediments and gases have been utilized. In the discussion of the circulation of descending and ascending waters almost nothing has been said in relation to the source of heat which raised the temperature of these waters. This is in part due to the fact that the problems involved are in great measure distinct from those treated here and time does not permit of their consideration, and in part because I know little about the matter. My opinions are still open to conviction. With this avowal I may be allowed to add that I am reluctant to believe that the source of the heated waters is, geologically speaking, deep-seated or sub-crustal.

In this connection it might not be out of place to mention the investigations of Professor Herman Schlundt and R. B. Moore, on the radioactivity of the thermal waters of Yellowstone National Park, conducted under the auspices of the U. S. Geological Survey, and recently published.[10] They found the rhyolites, limestones, thermal waters, gases, and sediments to be radioactive. Specimens of rhyolite from widely separated localities in the park were examined. These authors say:

> These data certainly seem to indicate that the hydrothermal activity so manifest in the park is

[10] "The Radioactivity of the Thermal Waters of the Yellowstone National Park," U. S. Geol. Survey Bull., No. 395, 1909.

not connected with localized deposits of radium. In the above calculations the question of heat lost by diffusion and other factors is not taken into consideration, but after allowing a generous margin for error we do not see how more than one per cent. of the heat required for the hydrothermal action can be ascribed to the radium content of the rocks.

Recently deposited travertine at the Mammoth Hot Springs, as well as that of the Main Terrace, and from the preglacial capping on Terrace Mountain, was subjected to similar tests. The same authors say:

The travertine of Terrace Mountain is overlain by glacial boulders. Since its activity is only one per cent. of the recent deposits its age is about 20,000 years, which would also be the approximate time tnat has elapsed since the glacial period in the park.

Furthermore, a sample of the Jurassic limestone underlying the Mammoth Hot Springs proved to be more radioactive than the most active sedimentary rocks tested by that eminent authority, R. J. Strutt, of England. It is noteworthy that the latter rocks referred to were specimens of the oolite formation from near the celebrated springs of Bath.

Strutt has also pointed out that siliceous igneous rocks are more radioactive than basic lavas,[11] a highly significant observation when it is borne in mind that the rhyolite of the Yellowstone National Park stands preeminent as an acid, crystalline rock. Iddings and Cross[12] have shown that allanite, in microscopic crystals, is widely but sparsely distributed in the siliceous igneous rocks of the Rocky Mountains, and has been detected in the rhyolite of Yellowstone National Park. Now allanite is known to carry small quantities of thorium. It is a coincidence worthy of note that thorium emanation was determined in several of the hot pools, it being first observed in this country in thermal waters in an obscure hot spring in Norris Basin. I see no reason, however, to doubt the conclusions of Messrs. Schlundt and Moore that the heat produced by radioactive emanations from the rocks and waters is wholly inadequate to meet the requirements. It seems necessary, at least from our present knowledge, to look elsewhere for the source of the heat dissipated by the thermal waters of the Yellowstone Park.

[11] R. J. Strutt, "On the Distribution of Radium in the Earth's Crust, and on the Earth's Internal Heat," *Proc. Roy Soc.*, Ser. A, Vol. LXXVII., 1906, p. 479.

[12] Jos. P. Iddings and Whitman Cross, *Am. Jour. Sci.*, 3d ser., Vol. 80, August, 1885, p. 108.

SUMMARY

In conclusion I may state that I have attempted to show (1) that igneous activity was continued throughout Tertiary time; (2) that this activity came to an end with the close of Pliocene time; (3) that during the Eocene and Miocene deep-seated waters were active geological agents, and that these waters were essentially primitive in their origin; (4) that in strong contrast to the explosive, volcanic conditions of the Miocene, the Pliocene lavas were emitted under far quieter conditions and built up the successive flows that formed the rhyolite plateau; (5) that during the many thousand years since the withdrawal of glacial ice, the Pliocene rhyolites have, since the beginning of Pleistocene time, been steadily undergoing progressive changes, brought about by the action of enormous volumes of superheated vadose waters; (6) that the gases contained in the thermal waters were in great measure derived from vadose sources; (7) that the eruptions and periodicity of geysers are phenomena due essentially to varying conditions of reservoirs and channels of superheated waters situated only short distances below the surface; (8) that the

phenomena, as seen to-day, represent a phase in the evolution of thermal springs.

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U. S. Geological Survey

HISTORIOMETRY AS AN EXACT SCIENCE

In the issue of Science for November 19, 1909, under the title "A New Name for a New Science" I proposed the term historiometry for that class of researches in which the facts of history have been subjected to statistical treatment according to some method of measurement more or less objective or impersonal in its nature. These researches have chiefly had in view the listing and grading of historical characters, either for the purpose of studying mental heredity or for the better appreciation of problems associated with the psychology of genius. Researches of this type are capable of a far greater expansion and application than is generally supposed. They can be applied to events as well as to individuals. They can, by treating the vast store of human records which exist in books as material for the construction of an exact science, work towards the solution of a wide range of historical problems, such as the causes underlying the rise and fall of nations or other fundamental questions in history.

Before anything can be done which shall give general satisfaction and agreement it will be necessary for this subdivision of science to justify itself, to measure its own shortcomings, to appreciate its own limitations, as well as to prove its own right to recognition of independent estate.

If we are to fathom historical causation by objective methods it is obligatory first to prove that history itself, as we commonly find it in the printed records, is a sufficiently valid account of what actually happened. Second, it is equally necessary to find proof that the objective methods correctly deal with these facts. It might be supposed that the second proof awaits the first; but this is not necessarily so. If the records themselves were very much at fault, so that the statements of historians were very far from ideal truth, or if the objective methods of collecting and analyzing these statements were subject to a large error (or if both these forces were in play) then it would be difficult to find wherein the trouble lay. But if, on the contrary, it fortunately be that history as we find it is in its important statements a fair representation of the truth, and if the methods of historiometry which deal with these records are also sound, then it is not difficult to prove both propositions at the same time.

I will give some instances to illustrate this, which show that such is the case for several types of historical records and for several methods of history measurement. This could not be done did we not possess some third criterion, some third standard of comparison of a non-historical nature. One such non-historical criterion is furnished by the known correlation ratios for resemblances between close blood relatives as determined in the anthropometric laboratory. These have been worked out and accurately measured for mental and moral traits, stature, head index and length of forearm. I have shown in "Heredity in Royalty"[1] that if the members of royal families are graded by the adjectives applied to them by historians and encyclopædists and then the coefficients of resemblance are measured between the near of kin, who have been so graded, these coefficients (historiometric) substantially agree with the anthropometric. Such would not be the case if historians perverted the truth greatly, or if for any other reason the truth were largely unattainable. To make this clear it is only necessary to think what the result would be if history were merely "a pack of lies agreed upon" as the extreme view puts it. We should then fail to properly pick out our true intellectual giants and runts. The result would be nothing but confusion. A whole series of errors would be distributed at random. This would act like rain on waves and flatten down to a common level the real differences between the individuals. The correlation measurements would fall and we should get no results comparable to those obtained from the delicate and ac-

[1] New York, Henry Holt, 1906.

curate measurements of the anthropometric laboratory.

Furthermore, any weakness in the method of grading, any failure to properly classify the great men in the high grades and the degenerates in their proper grades would work in precisely the same direction to lower the correlation coefficients. The supposed errors of history and the difficulties of grading act as two united strains of tension to pull the coefficients down towards zero, which would be the coefficient for random distribution. If the coefficient can stand the strain without declining, then, roughly speaking, we may conclude both that the historical foundation is just and that the method of procedure is sound.

There are two other illustrations of method which I would like to summarize here. One of these series of tests is the trying out of a standard biographical dictionary (historical persons) against two lists of contemporaries (non-historical persons) and all three in terms of still another set of facts, namely birthplaces of distinguished Americans. The second series of tests concerns the relative fame of Euripides *versus* Sophocles, the encyclopædias having been used and then this compared with expert modern criticism and both with the opinions of the Athenians.

As concerns American history, one fact is very evident at the start, whatever be the method of grading as applied to Americans or whatever be the mental eminence graded, some states in the union, some sections of the country, have produced more eminence than others far beyond the expectation from their respective white populations. In this regard Massachusetts always leads, and Connecticut is always second, and certain southern states are always behind, and fail to render their expected quota. I have already pointed out[2] that the ratios seem orderly for a first approximation. That is, the higher the grade of the individuals the greater and greater becomes the proportion of those born in Massachusetts. This may be expressed as a ratio, ρ into the random expectation. Thus if there were no forces at work beyond chance distribution the ratios for all sections of the country would be expressed by unity, $\rho = 1$. If there be found twice as many persons born in a certain locality as one would expect from the population let it be expressed as $\rho = 2$, three times as many, $\rho = 3$, etc. These ratios are easily computed and can be expressed as fractions or with decimals. I have computed these ratios for the thirteen original states, but will present here only the statistics from Massachusetts and Virginia.

It will be seen in Table I. that Massachusetts has never failed to produce twice as many eminent men as the population would lead one to expect, and has for some ranks and types of achievement produced about four times the expectation. ρ ranges between 2.1 and 4.7. Virginia, on the contrary, has but rarely produced as many as might be expected from the large white population and the ratios in the same table are either below the expectation or not significantly above it. The other New England states (statistics not here given) have all done more than their share, but always less than Massachusetts. New York gives a trivial though constant excess above the expectation. From here southward the ratios drop off suddenly, so that New Jersey, Delaware, Pennsylvania, Maryland, North Carolina and Georgia have always furnished less than their share. For South Carolina the ratios again rise and exceed the expectation, but only by the slightest measurable amount. North Carolina, of all the thirteen original states, has always had the worst record in the way of producing distinguished men; the ratios falling to about one quarter of what might be expected from the white population.

Regarding the tables for the two contrasted states, Massachusetts and Virginia, and following down through the columns marked "ratios, or number of times the random expectation according to the population at the approximate age of their birth," one sees first that the Massachusetts ratios run from 2.1 to 3.9 and the Virginia from 0.2 to 1.1. The higher Massachusetts ratios are associated

[2] "American Men of Science and the Question of Heredity," SCIENCE, N. S., Vol. XXX., No. 763, pp. 205–210, October 13, 1909.

with the lists of names in which the standards for admission to the lists are higher—that is, specially selected groups of the more eminent. Massachusetts also shows an extra merit when science or literature is alone considered, but this is merely an accentuation of some cause or causes which have enabled her to lead, no matter what type of success be the criterion.

There is also to be seen a probably significant gain in the ratios for Massachusetts from the census of 1790 to 1850. A further study of this special phenomenon might develop some interesting conclusions. The ratio also rises when only those in *Lippincott's* are considered who have received adjectives of praise. Nine tenths of the persons named in this dictionary are given a passing notice by the editors and nothing critical is said of their lives or their work beyond the barest record. About one tenth receive such adjectives of praise as "celebrated," "illustrious," "eminent," "famous," "noted," etc.

A priori we may suppose that these represent an extra superior group as compared with the other nine tenths. *A posteriori* the supposition is verified, because how else can be explained the rise in the ratio for Massachusetts from 2.8 to 3.8? If this "adjective method" did not select a superior group it would not raise the ratios, or in other words draw it further away from random hazard for which $\rho = 1$. The more accurately it seizes hold of the right persons and justly expresses real differences dependent upon natural causes the more it will raise this ratio. One can now see how it is possible in this way, and in similar ways, to actually test the validity of any method of selection. Its value depends, among other things, upon its ability to raise, or lower, a ratio in a proper degree, suitable to the case in hand, so that the ratios shall fit in, and harmonize with other ratios and other results.

If, for instance, the "space method," or the selecting the 234 men who have had the most space allotted to them in the dictionary, had not raised the Massachusetts ratio from 2.8 to any more than say 2.9 or 3.0 we might be justified in concluding that this method was inferior in accuracy to the "adjective method." As it turns out, it raises the ratio to 3.6. So one suspects that the "space method" is not quite as accurate as the "adjective method," since it does not raise the ratio as much though it deals with a smaller group. Of course one instance like this does not decide anything. I merely give it as an illustration of the ways in which historiometry may proceed.

I have also essayed a new method, namely selecting from *Lippincott's* a list composed of all those Americans whose biographies have been written and published in separate works. This constitutes a very small and presumably correspondingly select group, 129 in number. The ratio for Massachusetts is here seen to rise to 3.9, practically the maximum. It should of course do so if the method is sound and is successful in seizing hold of the right men. This may prove a very accurate, practical and rapid method of objectively listing great men in ancient or modern history, subject of course to such limitations and adjustments as special problems may require.

It can be seen that the general raising of the ratios is in no way dependent on the dictionary containing a large number of clergymen and writers. As a matter of fact, more than a third of the names are those of lawyers, bankers, merchants, politicians, government officials, soldiers, manufacturers and engineers. Here by narrowing the list from 1,266 to 232 and dealing with only a small group, we raise the ratio from 2.4 to 3. It might be supposed by some that a greater attention is shown Massachusetts by writers of books, biographies and histories because these writers live in the neighborhood. "Lippincott's Biographical Dictionary," however, is published in Philadelphia. Still it may be influenced by previous writings and earlier biographical dictionaries published in the neighborhood of Boston. If this is so to any appreciable extent then we should expect the ratio for Massachusetts to fall when present-day persons are graded by methods which have either nothing or little to do with historical traditions.

TABLE I

List of Names	Total in the List Born in U. S. A.	Number Born in Massachusetts	Number Born in Virginia	Ratios, or Number of Times the Random Expectation According to the Population at the Time of their Birth	
				Mass.	Virginia
Lippincott's "Biographical Dictionary," edition of 1895.	3,227	711	231	$\rho = 2.8$	$\rho = .6$
Same dictionary.					
Americans born A.D. 1785–A.D. 1794	302	75	22	$\rho = 2.1$	$\rho = .6$
Born A.D. 1795–A.D. 1804	370	79	25	$\rho = 2.2$	$\rho = .6$
Born A.D. 1805–A.D. 1814	464	96	23	$\rho = 2.6$	$\rho = .5$
Born A.D. 1815–A.D. 1824	513	97	33	$\rho = 2.9$	$\rho = .8$
Born A.D. 1825–A.D. 1834	363	74	19	$\rho = 3.6$	$\rho = .8$
Born A.D. 1835–A.D. 1854	343	58	15	$\rho = 3.5$	$\rho = .6$
Average of the above six lists	2,355	479	137	$\rho = 2.8$	$\rho = .65$
Same dictionary, Americans who have received any adjectives of praise	320	95	23	$\rho = 3.8$	$\rho = .6$
Same dictionary, Americans who have been allotted extra space (20 lines)	234	67	20	$\rho = 3.6$	$\rho = .8$
Same dictionary, Americans about whom books have been written	129	39	14	$\rho = 3.9$	$\rho = .9$
Same dictionary, practical types only. Bankers, merchants, lawyers, politicians, government officials, engineers, manufacturers, soldiers	1,266	235	143	$\rho = 3.4$	$\rho = 1.03$
Same dictionary, selected list of the greater among the practical types. (Adjective, space and biographical method combined.)	232	60	29	$\rho = 3.0$	$\rho = 1.1$
"Who's Who in America," edition 1908–09	14,227	1,650	493	$\rho = 2.6$	$\rho = .9$
"Who's Who in America," practical types only (initials A–C)	1,131	132	33	$\rho = 2.5$	$\rho = .8$
"Who's Who in America," lawyers, judges, congressmen, government officials (initials A–C)	580	60	23	$\rho = 2.2$	$\rho = .9$
"Who's Who in America," engineers, inventors, architects (A–C)	134	16	3	$\rho = 2.5$	$\rho = .5$
"Who's Who in America," army and navy (A–C)	170	18	5	$\rho = 2.5$	$\rho = .7$
"Who's Who in America," business men, financiers, railway officials, manufacturers (A–C)	247	38	2	$\rho = 3.2$	$\rho = .2$
"American Men of Science," 1906, all persons	about 4,000	436	not yet calculated	$\rho = 2.7$	
"American Men of Science," 1906, the leading thousand.	867	134	14	$\rho = 3.4$	$\rho = .4$
"American Men of Science," 1910, the leading thousand.	874	131	17	$\rho = 3.4$	$\rho = .5$
Hall of fame (list slightly extended as in SCIENCE, N.S., Vol. XXXII., No. 813, p. 158)	50	20	7	$\rho = 3.3$	$\rho = .9$

Two such methods of grading we fortunately possess in the compilations known as "Who's Who in America," and "American Men of Science." The ratios for Massachusetts do not fall. They dove-tail in with the ratios from *Lippincott's*. Hence we may conclude that the differentiations found in *Lippincott's* are not caused by unjust historical tradition and, furthermore, as far as one can see they are not in part caused by the same. "Who's Who in America" has been often used as an objective basis for sociological inquiries, but the criticism has been made that this book gives undue inclusion of authors and professors. I think this criticism is unjust. About forty per cent. of the whole fall under the more practical types enumerated in Table I. These I have considered separately as far as the initials A, B and C. They yield a ratio for Massachusetts of $\rho = 2.5$, which is very close to that for the whole book $\rho = 2.6$. The same for *Lippincott's* is $\rho = 2.4$, which is not in its exact theoretical position, as it should be higher than that drawn from "Who's Who in America." It will, of course, be appreciated that the clearing up of small disagreements like this requires further analysis and the computation of the probable errors.

The ratios from Virginia I present in this abstract merely as a general contrast to Massa-

chusetts. 1 prefer to make further statistical inquiries before attempting to interpret their meaning.

The third series of tests which illustrate the exactitude of historiometry are drawn from comparative studies of the fame of Euripides and Sophocles. In Science, October 7, 1910, Mr. C. A. Browne called attention to the fact that Sophocles received the first prize from the Athenians twenty times, and Euripides only four times, while since their deaths various writers from Plato to Emerson have referred to and quoted Euripides more than Sophocles. Mr. Browne also shows that both Curtius and Grote, and biographical dictionaries, and encyclopedias as well, allot more space to Euripides than they do to his elder rival. This seems to indicate that the opinion of the Athenians has been reversed by posterity, but the real explanation I have found to be otherwise.

TABLE II

Authorities	Sophocles			Euripides		
	Space Lines or Pages	Adjectives		Space Lines or Pages	Adjectives	
		Pro	Con		Pro	Con
Bergk, "Griechischer literaturgeschichte," 1894	110 pp	128	28	137 pp	100	64
Bernhardy	74 pp	71	23	116 pp	105	97
Croiset	57 pp	115	13	71 pp	132	57
von Christ	34 pp	46	3	40 pp	35	20
Curtius	200 ls	25	0	773 ls	36	20
Müller and Donaldson	25 pp	31	3	30 pp	17	14
R. C. Jebb	11 pp	16	0	16 pp	24	11
Gilbert Murray	19 pp	31	4	28 pp	15	6
Jevons	11 pp	14	0	13 pp	19	9
Encyclopedias						
Meyer's "Konvasations Lexikon"	109 ls	9	0	126 ls	8	2
Brockhaus' "Lexikon"	112 ls	6	0	161 ls	2	1
"La Grande Encyclopédie"	298 ls	27	1	178 ls	5	1
"Encyclopaedia Britannica," 1890	550 ls	22	0	995 ls	10	4
"New International Encyclopedia"	207 ls	10	2	181 ls	7	3
Lippincott's "Biographical Dictionary," 1892	52 ls	8	0	45 ls	6	0

It appears that the problem that Mr. Browne proposes is a very delicate one. These two great Greek dramatists stand in such an exalted position and so close to one another, both being near the extreme range of human genius, that probably not two hundred individuals who have ever lived have exceeded them in eminence.[3] Therefore, compared with all men of all historical time, these two are almost merged in something like a point at the extreme end of a line. It is like splitting and measuring the components of a binary star at a great distance. It would be no discredit to any objective method of differentiation if it failed to give interpretable conclusions. As it is, it turns out that the problem presented is just within the limits of historiometric discrimination so that the figures yield uniformity and repetition warranting real conclusions.

I have extended Mr. Browne's list and have found confirmation of the statement that more space is devoted to Euripides than to Sophocles. This would leave the impression that Euripides is to-day frankly considered the greater of the two, which is not the impression that one gains by even a cursory reading of the printed matter so spaced. Furthermore, I am informed by John Williams White, Professor of Greek, Emeritus in Harvard University, that for the last hundred years the general estimate of scholars has placed Sophocles above Euripides. This is precisely the conclusion which is obtained from the extraordinary character of some of the terms and sentences of eulogism which one finds applied to Sophocles. In these same authorities one never finds for Euripides anything like the following: "There has hardly been any poet whose works can be compared with those of Sophocles for the universality and durability of their moral significance . . . of all poets of antiquity Sophocles has penetrated most deeply into the recesses of the human heart" (Müller and Donaldson). "He renders tragedy a perfect work of ideal art" (R. C. Jebb). Occasionally the direct comparison is

[3] Conf. J. McK. Cattell, *The Popular Science Monthly*, February, 1903, p. 359.

made and then Euripides suffers; for instance, as when Gilbert Murray says:

> No wonder Sophocles won four times as many prizes as Euripedes. . . . Sophocles shows at times one high power which but few of the world's poets share with him. . . . in the second Œdipus there is a certain depth of calm feeling unfettered by any movement of mere intellect, which at times makes the subtlest and boldest work of Euripides seem "young man's poetry" by comparison.

It can be easily seen that this general impression can be checked up and is unfailingly expressed by each ratio of the adjectives of praise (pro) against those of dispraise (con). For every single authority consulted the answer is the same,—the proportionate ratio favors Sophocles.[4]

The "space method" fails here to give a verdict agreeing with modern and ancient opinion probably for special reasons peculiar to the case. More plays of Euripides are extant and there is more to be said in the way of adverse or qualifying criticism. It is not to be denied that the interest in Euripides is, and always has been, intense, perhaps greater than in Sophocles, but the position of the latter is more majestic and more sublime. The lexicons alone would have given this conclusion in a few minutes reading. All these facts, in connection with those taken from Lippincott's dictionary, indicate that the "adjective method" is a very delicate way of measuring small differences if for any reason it is desirable to do so.

The questions here touched upon concern only the individuals, but I know from material as yet unpublished that the quantitative objective method can be applied to events as well as to persons. If its validity for the study of individuals can be securely grounded, then its application to events will naturally follow and will be thereby the more easily and surely established.

Space has permitted only a brief abstract, but I think that enough has been given to prove that researches of this nature furnish harmony and order, intertwine and mutually support each other, form an organic structure, and are entitled to recognition among the exact sciences. It must be remembered that exactitude in science is a relative term. Abstract mathematics may be exact, but no science of physical measurement is really exact. Astronomy, which is usually thought of in this way, only gives an approach towards an ever-expanding ideal. No two observers have ever quite agreed upon the latitude of the Greenwich observatory and the last transit of Venus was, if I remember rightly, in comparison with the computed prediction, some eleven seconds off. All we ask is that the exactitude shall be sufficient for the practical needs of the problem in hand.

I think it must be agreed that this first synthesis and coordination of isolated researches presents a very encouraging picture. It indeed gives proof that a workable instrument has been obtained capable not only of dealing with questions as intricate as human nature and its attributes, but actually at the same time demonstrating the essential validity of the historical data on which are based the percentile grades, ratios, correlations or other super-structure. This latter conception is to me the most interesting side of the whole matter. It has usually been impossible to scientifically refute those critics who claim that the so-called facts of history are so uncertain and subject to so great an error and prejudice that it is unsafe to build conclusions upon them by statistical methods. They have not of course ever known that such was the case nor have they ever had any way of estimating how far the records of history, as they exist in standard works, encyclopedias and biographical dictionaries, actually deviate from the absolute truth. It has been assumed, on the other hand, by those who have been engaged in grading historical characters, that the records represent a fair approximation towards the ideal truth. The human record which we call history stands somewhere between two extremes, somewhere between the quagmire of complete falsehood and heights of perfect truth. It is possible as we go on to appreciate, with closer and

[4] In this part of the work I have had the assistance of Mr. A. A. Jenkins, of the Harvard Law School.

closer accuracy, just what deviation from ideal truth any great set of historical records contains.

Such researches give promise of at last furnishing the long-sought correct method of penetrating the tangled and perplexing jungle known as philosophy of history. This domain of thought is to-day in poor esteem among those who, as historians of the modern school, seek in documentary sources to reconstruct the past around some central theme, some individual age or nation. No wonder these careful investigators have become disgusted with the *a priori* dogmatism, the partizan spirit, the free generalizations from half truths and the eternally conflicting conclusions. Historical philosophers, in their desire to explain everything at once, have been content to formulate theories and then pick from the totality of history, selected facts to support them. With methods highly subjective, and carrying a large personal equation they could not help but find exactly what they wished. The ways of inductive science may be slow at first, but even a small nucleus of collected and coordinated facts soon grows with astonishing rapidity; and every objectively established piece of work makes it, with accelerated speed that much easier to progress along lines of certainty and exactitude.

Frederick Adams Woods
Massachusetts Institute
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SCIENTIFIC NOTES AND NEWS

Lord Curzon will succeed Major Leonard Darwin as president of the Royal Geographical Society.

The Bessemer gold medal of the Iron and Steel Institute, London, will, this year, be awarded to Professor Henri Le Chatelier, the French metallurgist. The Andrew Carnegie gold medal for 1910 will be awarded to M. Félix Robin, of Paris.

A complimentary dinner was given on March 29 by former students of King's College Hospital to Sir David Ferrier, M.D., F.R.S., to congratulate him on receiving the honor of knighthood.

Dr. Lucius L. Hubbard has been appointed regent of the University of Michigan. He has been instructor in mineralogy at the State Mining School at Houghton, Mich., and was state geologist from 1893 to 1899.

Mr. George Henry Livens, B.A., has been elected to a fellowship at Jesus College, Cambridge. His subject is mathematics.

Dr. Edna Carter, instructor in physics at Vassar College, has been awarded the Sarah Berliner research fellowship for women. She will continue her work in physics at Cambridge under Professor J. J. Thomson, and in the laboratory of Professor Wein, of Würzburg, where she received her doctorate.

The annual awards of the Royal Geographical Society are announced as follows: The two royal medals have been awarded, the Founder's to Colonel P. K. Kozloff, and the Patron's to Dr. J. Charcot. The Victoria Research Medal has been given to Captain H. G. Lyons, the Murchison Bequest to Dr. Wilfred Grenfell, the Gill Memorial to Captain G. E. Leachman (Royal Sussex Regiment), the Back Bequest to Dr. Arthur Neve, and the Cuthbert Peek Fund to Mr. R. L. Reid.

Dr. H. F. Moore, of the U. S. Bureau of Fisheries, has sailed for Rome where he will represent the Bureau at the fifth International Fishery Congress to be held May 26–31. Before returning he will visit the coast of Algiers for an examination of the sponge fisheries.

An expedition under Mr. Homer B. Dill, of the State University of Iowa, has left San Francisco for Laysan Islands in order to study the bird life and bring back specimens for an extensive group to be placed in the museum.

Professor F. E. Lloyd, of the Alabama Polytechnic Institute, is planning a trip into the Arizona Desert this summer, in order to continue his botanical researches in desert plant life.

According to the *Bulletin* of the American Mathematical Society, Professors E. R. Hedrick, of the University of Missouri, and J. I. Hutchinson, of Cornell University, have been

granted leave of absence during the second half of the present academic year; they will spend most of their time in Paris. Professors E. J. Wilczynski, of the University of Chicago, and C. L. Bouton and J. L. Love, of Harvard University, are also spending the present half-year abroad on leaves of absence.

PROFESSOR HAROLD B. SMITH, director of the department of electrical engineering at the Worcester Polytechnic Institute, lectured before the Cornell branch of the American Institute of Electrical Engineers on March 31. His subject was "Some Engineering Developments of the Electric Field of Force."

ON April 5, 1911, the University of Pennsylvania Chapter of the Society of the Sigma Xi initiated sixty-eight new members. Thirty-three of them are alumni of the university who graduated before the organization of the chapter and have since attained prominence in scientific work. Eleven are members of the faculty and twenty-four are undergraduates. The address to the initiates on "The Two Fields of Activity of the Learned Professions," was made by Professor I. J. Schwatt, president of the chapter, and the society was addressed by Professor Allen J. Smith, dean of the medical department, on the subject, "Schools of Applied Science in Relation to the Graduate School."

MR. HENRY A. PURDIE, of Boston, one of the founders of the American Ornithologists' Union and long identified with the ornithology and botany of New England, died at the Massachusetts General Hospital on March 29 and was buried at Mt. Auburn Cemetery, Cambridge, April 1.

MR. BERNARD AMEND, president of the firm of Eimer & Amend, and a former student of von Liebig, died in New York City on April 6, at the age of ninety years.

ALPHONSE LOUIS PIUART, a French traveler and philologist, died at Boulogne (Seine) on February 13, at the age of fifty-nine years.

THE biological laboratory of the United States Bureau of Fisheries at Woods Hole, Mass., will open early in the coming June, for the twenty-seventh season since its establishment in the present quarters. A limited number of research rooms and tables will, as usual, be placed at the disposal of those qualified to conduct investigations in the various branches of marine biology. Applications should be sent at an early date either to the commissioner of fisheries, Washington, D. C., or to the director of the laboratory, Woods Hole, Mass.

THE twentieth session of the Marine Biological Laboratory of Stanford University will begin Wednesday, May 31, 1911. The regular course of instruction will continue six weeks, closing July 11. Investigators and students working without instruction may make arrangements to continue their work through the summer. The laboratory will be under the general supervision of Professor F. M. McFarland, instructor in charge.

THE Society of College Teachers of Education has entered into an agreement with the University Press of Chicago whereby the editorial management of the *School Review* will henceforth be under the control of an editorial committee elected by the society. This editorial committee consists of Professor M. V. O'Shea, president of the society and chairman of the department of education, of the University of Wisconsin; Professor E. O. Holland, secretary of the society and professor of education in the University of Indiana; Professor William C. Bagley, director of the school of education, University of Illinois; Professor Frederick E. Bolton, director of the school of education, University of Iowa, and Professor Paul H. Hanus, head of the department of education, Harvard University. To this editorial committee representing the Society of College Teachers of Education has been added Professor Willard C. Gore, Professor Frank N. Freeman and Professor Franklin W. Johnson, all of the faculty of the school of education of the University of Chicago. Professor Gore has been elected by the committee managing editor of the *Review*. As a result of this agreement, the *School Review* will become the organ of the Society of College Teachers of Education. It is

planned to make it of service to all who are concerned in any way with secondary education in this country. It has been decided also to publish in connection with the *Review* a series of supplementary monographs dealing in a detailed and scientific way with problems of secondary education.

In the examination for resident engineer, Department of the New York State Engineer, the time for receiving applications has been extended to April 20, 1911, and the requirements for admission amended as given below. Resident engineer, Department of State Engineer and Surveyor, salary $2,400 to $3,000. Applicants must have at least five years' practical experience in civil engineering, three years of which must have been in responsible charge of work. Graduation from an engineering school of recognized standing will be accepted in lieu of one year of the five years' experience demanded. While candidates will not be assembled for a written examination, they may be summoned for an interview with the examiners. Subjects of examination and relative weights: Experience, education and personal qualifications, to be rated upon the candidates' detailed statements and upon answers to inquiries which the commission may direct to previous employers and others acquainted with their experience and qualifications and upon the oral examination, 1; two theses—a report upon some work of importance carried out under the charge of the candidate, and a discussion of some assigned topic relating to the problems to be handled in the construction of the barge canal, 1. The theses are to be written and submitted by the candidate in accordance with instructions to be issued by the commission, of which due notice will be sent to those who file applications. Non-residents will be admitted, subject to the provisions of civil service regulation X., that in case the eligible list contains the names of three or more citizen residents of New York state, they shall be preferred in certification over non-residents.

The summer field session for 1911 of the School of American Archeology of the Archeological Institute of America, will be held at El Rito de los Frijoles, near Santa Fé, New Mexico. Facilities will be given students to observe or to participate in the excavations, begun in 1908, and now in progress at Tyuonyi, near-by talus pueblos and cliff-dwellings. Excursions will be made to facilitate a study of botanical and other environmental conditions of the tribes dwelling in the vicinity. During August, lectures will be given on the distribution and culture of the tribes in the southwestern section of the United States; on the evolution of design as shown in ancient Pueblo art; on the native languages, and methods of recording them. A course will be given by Dr. Lewis B. Paton, formerly director of the American School in Jerusalem of the Archeological Institute of America, on "The Ancient Semites" to afford an opportunity of a comparative study of cultures developed in semi-arid regions in the eastern and in the western continents. Other lectures for comparative studies are being arranged for. The object of the annual summer field session of the School of American Archeology is to bring together persons interested in the study of anthropology, for first-hand investigation and discussion, and to give students the opportunity for field work needed to supplement university instruction. The attention of teachers and students engaged in the scientific study of education is also called to the advantages of this work. At the close of the session opportunity will be given to visit the pueblos of Taos and Acoma, and the government excavations among the cliff-dwellings in the Mesa Verde National Park, Colorado. For details of the summer session, address *Director of the School of American Archeology,* Santa Fé, New Mexico.

The sundry civil bill passed March 4, 1911, by the late congress provided for a reorganization and expansion of the Alaskan interests of the U. S. Bureau of Fisheries. A new division of the bureau is created, the Alaska Fisheries Service, to hold the affairs of the fur-seal, salmon and other fisheries, and of the fur-bearing animals. The latter field is an entirely new extension of federal super-

vision, under the act of April 21, 1910, vesting control in the hands of the secretary of commerce and labor. The fur-seal and salmon fisheries have been for years under federal control, and are now taken out of the division of scientific inquiry, unifying under one head the whole Alaskan service. The new division has a total personnel of 25 persons and an annual salary appropriation of $41,530. Of the personnel, eleven positions are new ones and consist of the chief, an assistant chief, three clerks, one assistant salmon agent, one warden and four deputy wardens. The increases apply mainly to the fur-bearing animals and the salmon fisheries, the fur-seal service having received in the year preceding additions to its personnel, made necessary by the expiration of the lease of the Pribilofs and the taking over by the government of the entire business of taking and selling seal-skins. The chief of the Alaska Fisheries Service will be Dr. Barton W. Evermann, for eight years chief of the Division of Scientific Inquiry. Dr. H. F. Moore, for eight years principal scientific assistant in the Division of Scientific Inquiry, succeeds Dr. Evermann as chief of that division. Mr. M. C. Marsh remains as chief Alaska salmon agent and Mr. Walter I. Lembkey as chief fur-seal agent.

UNIVERSITY AND EDUCATIONAL NEWS

THROOP POLYTECHNIC INSTITUTE, Pasadena, Cal., has received for endowment four gifts aggregating a quarter of a million dollars. The largest is $150,000, there is one of $50,000, and there are two of $25,000 each. The income becomes available after July 1, 1911.

MR. JAMES A. PATTEN has added $50,000 to the $200,000 which he had given to the Northwestern Medical School for the study of tuberculosis.

A BUREAU of research in municipal government is to be established at Harvard University, to be maintained by a gift of $2,500 a year for ten years offered by Mr. Frank Graham Thomson, of the class of 1897, and Mr. Clarke Thomson, of the class of 1899, both of Philadelphia, Pa. Professor W. B. Munro is to direct the work of the bureau. In connection with this bureau material bearing on national and state government is to be collected, the work to be maintained by an anonymous gift of $1,000 a year for five years; Dr. Arthur N. Holcombe, instructor in government, is to be in charge.

MISS MARY ANNE EWART has bequeathed £20,000 to Newnham College, Cambridge, for scholarships for women students and £10,000 to Somerville College, Oxford, for like purposes.

NORTHWESTERN UNIVERSITY has arranged an architectural competition for the development of the university campus. It is proposed to erect at once dormitories costing $150,000 and in the near future an academic building costing about $180,000.

THE upper wall of the west tower of the William Rainey Harper Memorial Library, in course of construction at the University of Chicago, has fallen, demolishing the interior of the tower from top to bottom. The loss, which falls on the contractors, is estimated at $50,000.

PLANS for the first summer session of the Johns Hopkins University have been announced. Work will begin on July 5 and will last six weeks.

THE Nebraska legislature, reversing a previous vote, has permitted the University of Nebraska to apply for admission to the benefits of the Carnegie Foundation.

BOWDOIN COLLEGE proposes to adopt a plan for admission to college similar to that of Harvard. Students are required to present a record of their school studies and to pass an examination in four subjects only.

DR. L. H. MURLIN, president of Baker University, has accepted the presidency of Boston University.

MR. WILLIAM J. DUPPERT, of the United States Forestry Service, has been appointed instructor in forestry at the University of Nebraska to take part of the work of the late Professor Frank J. Phillips.

Mr. A. Franklin Shull, assistant in zoology in Columbia University, has been appointed acting assistant professor of zoology at the University of Michigan, to succeed Dr. A. S. Pearse, who has gone to the University of Manila.

Mr. Dunham Jackson, now studying at Göttingen on a Harvard traveling fellowship, has been appointed instructor in mathematics at Harvard University.

At the Normal College, New York City, Charles T. Kirk, instructor, has been promoted to be assistant professor of geology, and Miss Emily O. Long, to be assistant professor of botany.

DISCUSSION AND CORRESPONDENCE

THE METHOD OF SCIENCE, A REPLY

A recent number of Science (January 27, 1911), has a forceful address by Dr. Minot on the "Method of Science." It is a new presentation of a topic fully discussed from the attitude of pre-evolutionary thought, but in such a manner and from such premises that its logic can not serve as a basis of present problems. I do not have the feeling of disrespect for the old thought that Dr. Minot seemingly has, but I agree with him that its principles and methods give little help in solving the problems science now faces. But at this point our differences begin, for in his restatement of principles, admirable as it is, he cuts the ground from under the social sciences by putting up standards that they can not meet. I do not think he meant to do this, yet the feeling he shows against the old philosophy warrants the inference that he would pass a similar judgment on the results of social science.

A new statement of the laws of thought is certainly needed. Early logic was devised by the theologians to prove the existence of supersensual units. As instruments for this end the so-called laws of thought are effective. But we need other rules to solve present problems. Not only is this so, but the methods of investigation have been so altered during the past fifty years as to create new problems. Accurate measurements are a new device. There were cases of accurate measurement before the present epoch, but they were not numerous enough to create a peculiar type of reasoning and thus to force a revision of the rules of logic.

The old division was between inductive and deductive logic. This controversy is now practically dead and in its place is arising one between inductions based on observation and those on experiment. Observations are generalizations under complex conditions, while experiment means isolation, simplicity of environment and accurate measurement. Workers in physical science distrust observations and demand in their place carefully verified results. This change is not a matter of theory, but due to practical situations faced by scientists in their various fields. The new medicine of which Dr. Minot is so good a representative gives an excellent illustration of the situation that forces him to attempt a reformulation of the laws of thought. The old practitioner was an observer: he diagnosed cases from symptoms. The new school experiments and measures. To say that science is exact measurement means practically to shut out the old physician who carried his knowledge in his head and whose office was not a chemical laboratory.

But if the laws of thought needed to shut diagnosis out of medicine are formulated as general laws, rules are set up that exclude all social judgments derived from observation. The tendency to do this is already visible in biologic sociology whose premises are taken bodily from biology. Bold deductions are made and conclusions drawn that sweep aside all generalizations based on observation. Here is a sample of reasoning of which we will have many more if Dr. Minot's rules of thinking win acceptance. I quote from a recent magazine article. "No generalization has ever exercised such a far-reaching effect on thought as the theory of natural selection. It is hardly necessary to point out that the corresponding belief in sociology is that all progress must come from the gifted individual, from the 'sport' who survives as the best of his kind. Darwinism lays stress not on the democratic

mass and their comfort, but on the few men of talent and their incomparable value to society." The essence of this position is the same as Dr. Minot's[1] exact well-proven premises, a distrust of observation and the conviction that scientists seldom err except in their measurements. This leads to long-range deductions and a neglect of verification within the field, where the conclusions are drawn.

Such methods reflecting the growing tendency in science to disregard observation force those who use it to rise in its defence. A controversy of this kind could not have arisen earlier because no one then questioned the validity of observation. If, however, science has come to mean exact measurement and laws of thought are formulated in harmony with the new view, observation must also have its laws restated or its results will be questioned not in a few fields but in every part of scientific research.

When we seek to demark the field of observation from that of experiment, it will be seen that experiment is carried on under local specific conditions. Only when an object is isolated and its environing conditions definitely fixed can the accurate measurements be made upon which the success of an experiment depends. Observations, however, are made under complex conditions and usually they cover a large area of space or time. The essence of an observation is to fix on some mark or characteristic of an object through which it may be recognized. Reasoning through observation joins two such marks in the relation of cause and effect. If "X" is always followed by "Y" the object of which "X" is a part is the cause of the object or event of which "Y" is a mark. In observation wholes are thought of in terms of some of their definite marks and thus reasoning becomes a connecting of these marks in some casual relation. In contrast to this procedure the "X" and the "Y" of an experiment are isolated from the wholes to which they ordinarily belong. Their qualities and relations can thus be accurately measured and described.

If this is the difference between observation and experiment, the mode of thinking used by the workers in the various sciences can also be contrasted. There are four types of reasoning whose peculiarities depend upon the use made of observation and experiment. The first group affirms that science is measurement and thus rules out observation. This group of thinkers is of recent origin because the means of accurate measurement are a recent discovery. It is no wonder that Dr. Minot found books on logic useless, for early logic gave rules for observation and deduction but did not recognize measurement as a means of investigation. Now we have whole sciences within which measurement is the main source of progress whose workers are so effectively organized that observers of the older type are frowned down or excluded. A social caste is thus formed who set up standards of their own and who issue a "Who is Who" of learned men from which they exclude those using observation as a method of research.

The second method has become popular through the discussions of heredity that Dr. Weismann began. This assumes that if we have two series of events both measurable and certain the first is not only the cause but the sole cause of the second. If, for example, there is a definite alteration of the hand it must have been caused by an antecedent modification of the germ cell of the organism. All observations of the hand and all other sources of modification except those of germ-cells are shut out and a bold deduction is put in their place. The method of this group thus includes nothing but measurement and bold unverifiable deductions. They are playing havoc in the social sciences because their deductions become the basis of biologic sociology.

If we pass from the sciences using experiment and measurement to the social sciences that depend on observation, we likewise find

[1] I refer to such sentences as these: "A broad examination of the method of science reduces itself to the study of the general principles of securing accuracy." "It must be doubted very seriously whether the study of logic is really essential for the right training of an investigator." "It is my belief that the logical work of scientific men is usually well done and is the part of their work which is the least faulty."

two groups. The method of investigation correspondingly changes since social science can not readily get at causes by experiment but must begin with observation of results and work back towards causes by indirect methods. This method has lately been renamed pragmatism and involves a judgment of causes through their effects. Consequences are open to observation; causes are not. A cause must therefore be judged by its observed effects. The leading exponent of this method was the late Professor James. I do not wish to defend his arguments, but to call attention to his method. His observations—those on which truth depends—are psychic phenomena. We may therefore call this method psychic pragmatism, for the satisfaction that the perception of truth affords becomes its test. There is, however, another method that goes out from consequences just as Professor James does but which uses objective social tests instead of psychic tests. Social pragmatism uses marks to visualize wholes, but the marks are the objective social consequences of acts which can be measured and verified. Social consequences can be measured and through their observation a steady advance is possible in ways that will put social observation on a par with physical measurements as a means of developing science.

If it can be agreed upon that observation and experiment furnish the only basis upon which investigations can rest the next subject of importance is the canons of reasoning. Dr. Minot assumes that the reasoning of scientists is seldom defective and that their main errors are those of measurement. Scientists however, are as liable to errors of logic as other people and scientific method can not disregard the laws of thought. They are the very essence of good thinking and must therefore be formulated.

The first and primary rule is that only observations and experiments can be used as premises in deductions. This seems an innocent rule, but it involves more than at first sight is apparent. All experiments are local and specific in their conditions. There is no such thing as a general experiment and hence premises derived from them are local definite facts. The same is even more true of observations. They are made by individuals and no one can extend his observations over more than a local field. All valid data are therefore local and specific. Reasoning consists in extending the scope of these premises to other and broader fields. It follows from this that there is no difference in kind between an induction and a deduction. This distinction is due to the well-deserved disrepute into which the dogmatic assertions of theologians and metaphysicians fell. Scientists wanted therefore to get a peculiar mode of reasoning that would avoid these evils. In this they have failed. So many sciences have become deductive that the reasoning of scientists differ in no essential respect from that of any other group. The differences are in the premises and in the verifications, not in the reasoning. There is but one method of reasoning. Its rules apply to all thought and to all subjects. The same end that the distinction between inductive and deductive thought is attained by the second rule of good thinking. No generalization should be used as a premise in reasoning. A generalization is a result of previous thought and is only an approximate truth. Every new chain of reasoning must go back to the original data in the form of observations and experiments and be based on them together with the new data obtained since the original generalization was made. The chief violations of this rule are in social science, but scientists are not free from this error. They, like other people, form themselves into social groups and thus acquire dogmas and prejudices that induce them to use the generalizations of their group as premises when they should confine themselves to their data in the form of observations and experiments. Sound reasoning always goes from the local to the general. Universals are made either by some social group imputing value to a premise that serves their practical needs or they are loose generalizations based on imperfect data. Whatever their source, they are unsafe premises and lead to widespread popular errors.

From this it follows as a third canon of thought that all conclusions need an independent verification. If reasoning from generalizations were permissible and thought could legitimately move from an acknowledged universal to a particular, verifications would not be necessary. It is interesting to see the many ways in which thinkers try to avoid the need of verification. From this temptation scientists are no freer than other thinkers and they have furnished many notable examples of such errors. Verifications are, however, always necessary and they must be based on fresh data. Reasoning merely points out where these data exist and what data are pertinent. The work of getting at the truth is only half done when the conclusions drawn from premises are shown to be valid.

Thought is the connection between two objects or ideas brought about by the similarity or dissimilarity of their inherent elements. Progress in thought consists in passing from indefinite marks of this identity or difference to those capable of definite description and measurement. This fourth rule of good thinking brings out the relation between observation and measurement. Verifications are improved when observations are verified by experiment and experiment by observation. Only in this way can we be sure that the data of the verification are independent of those of the premises. There is a still further improvement when enunciated principles are based on observation and their verification consists of data arising from experiment and measurement. Such proofs are the most stable science can offer. It is a goal that can not always be reached, but it should always be striven for. Principles are most readily obtained from observation; their proof, however, is complete only when measurable data afford them a verification.

A final rule of thought is that no law is to be regarded general unless it is capable of independent statement and verification in many fields of investigation. This is the doctrine of multiple verification. It is often assumed that the way to prove a law is to get more data in some one field. Such a proof is less satisfactory than independent verifications coming from data derived from other sciences. It is the extension and restatements of a law in other fields and by independent investigators that raise its validity above local generalizations which have both time and space limitations. All observations and experiments are of this local character. They need multiple verifications to make them worthy of general acceptance. It is a corollary of this that thought is improved not by additional erudition in a given field, but by the movement of thinkers from field to field. There is a strong tendency to resent such a movement and the intruder is likely to receive rough treatment by his new colleagues. Yet this has been the way in which the greatest victories of thought are won. If Pasteur had not passed from chemistry to medicine his work might have been scientific, but it would not have been effective. Narrow specialization tends to such complete isolation of a group that its activity becomes socially valueless. The mobility of thinkers is the only safeguard against these evils. It makes trouble but it brings results.

Two conclusions follow from the preceding discussion. The first is that there is but one true method of reasoning in the use of which all are equally liable to error. The second is that there are two kinds of data, observations and experiments, both of which must form a part of any complete verification. These general statements would be of little use if they were not applied to the problems that separate social from physical science. While the opposition is general it is focused upon the controversies about man and his relations to the animal world. The one group use as their data the experimental knowledge of animals and then sweepingly apply this knowledge to man. "What is true of dogs is true of men" is a dictum coming from deductive medicine which illustrates the methods of all biologic sociologists. On the other side, there are social laws established by observation which have been accepted by the mass of mankind as rules of conduct: Which of these is right both in method and fact?

In the first place, it should be recognized

that men can not be put in laboratories and experimented on. It would seem, therefore, that observation must have a place in studies of man that it need not have in animal investigations. In the second place, the tests between the two methods do not lie in problems of normal development, but of pathology and degeneration. There are few observations about normality that are worth much. Social observations are mainly about defects and abnormalities. Keeping these facts in mind, the issue is clear. I will state it in the words of Dr. F. A. Woods. "Experimentally and statistically there is not a grain of proof that ordinarily environment can alter the salient mental and moral traits in any measurable degree from what they were predetermined to be through innate influences."[2] To test such a statement it must first be asked what are "mental and moral traits." If Dr. Woods means traits like sympathy, I agree with him. I know of no observational evidence showing it can be altered except by organic development. This may be true of all positive characters. But many so-called characters are not positive traits, but merely conditions. We can not make good men better merely by an environmental change but we can in this way eliminate vice. Is there then a difference between a condition that leads to degeneration and a biologic trait that is necessary for progress? To be specific, are drunkenness, hysteria and criminal tendencies conditions having objective causes or are they biologic characters? Social observers point out what the conditions are that bring on these results and contend that the so-called traits appear and disappear with the presence or absence of given objective conditions. The deductive biologists start with premises about germ cells and apply their conclusions to man without verification. The difference is not one of fact, but of the sufficiency of bold reasoning.

If, as Dr. Minot asserts, scientists seldom err in conclusions when their measurements are exact the weight of authority is with theorists. I am not so sure of this as he is. The weakness seems to me to lie in the difference between the conditions of man's survival and those of lower animals. Before the rise of social sentiments elimination acted sharply against the defective individual, and hence degeneration could not become prominent. Then all traits were traits of survival and few pathological states appeared. Man, however, through sympathy preserves the weak and hence lowers the average man below his normal condition. If we regard one hundred points as the normal level in the animal world the lack of ten points would lead to elimination. In human society, however, a man could lack forty points and yet perpetuate his kind. I do not wish to attempt a mathematical demonstration, but it is plain that human sympathy reduces materially the sharpness of elimination. Sympathy could not act in this way if society did not have a surplus that it used to maintain the defectives. Sympathy is thus the indirect cause of the failure of elimination, but a condition of surplus is its direct cause. If it were absent, only normal people and normal traits would survive.

There are two objective conditions that reflect themselves in abnormal traits, a condition of surplus and a condition of deficit. The traits due to a surplus are usually called vices, while those of deficit are called crimes. These terms are not sharply contrasted, but their use is definite enough to illustrate my meaning. Give men more than they need and they sink into vice: take from them what they need and they become criminal. If vices and crimes can be changed or removed by altering income conditions we have proof that vicious and criminal traits are not biologic but economic in origin. We can then conclude that abnormal traits are not true biologic characters, but the impressment of economic conditions which are modified as the environment gives a surplus or deficit to those within it. A condition of deficit desocializes those who suffer from it and thus brings out atavistic traits not appearing in normal persons. A condition of surplus making people emotional, morbid and hysterical undermines the power of the will. Deficit people can be said to be

[2] *The Popular Science Monthly*, April, 1910.

too willful, while surplus people are almost will-less.

I do not use this argument to show that my position is correct but to make clear what it is on which the contrasted arguments rest. The biologic sociologists are using bold deductive arguments without a verification. Their position has plausibility only by ignoring observational evidence. Deductive medicine with its neglect of diagnosis puts itself in the same position. The one group affirms that what is true of germ cells is true at maturity while the other says what is true of dogs holds for men. This is reasoning, not observation or experiment.

It is said of Agassiz that he took his students out to a great boulder near Cambridge and asked them what they saw on it. Some saw nothing: others saw vague scratches. Only he saw the ice-markings and proof that the boulder was deposited by a glacier. By the methods of to-day instead of these observations we would have exact measurements of the scratches: their depth and length would be carefully ascertained, and finally the Carnegie Institution would be asked to make a grant for weighing the stone. In this way note-books would be filled and a reputation made, but who will say all this is worth as much as what Agassiz saw with his unaided eye? Logic has pitfalls for all of us: we escape from our errors only by shrewd observations and multiple verifications.

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MIASTOR LARVÆ

THESE remarkably interesting larvæ, reproduced by pedogenesis, are available for laboratory work to a marked degree and must be widely distributed as well as allied forms. Very little is known concerning American species, largely because their habitat is one rarely explored by entomologists. They breed mostly in decaying vegetable matter. We have been very successful in finding them under partially decayed chestnut bark of stumps, fence rails and sleepers which have been cut one or two years earlier. European species have been observed under the bark of a variety of trees and even in sugar beet residue. These dipterous maggots with diverging antennæ have a flattened, triangular head quite different from the strongly convex, usually fuscous head of the *Sciara* larvæ occurring in a similar environment. They have a length of from one twentieth to one eighth of an inch and may be found in colonies containing a few large, white larvæ with numerous smaller, yellowish individuals, though the latter appear more common at the present time. Early spring with its abundance of moist bark appears to be the most favorable season for finding the larvæ. The writer would welcome the cooperation of entomologists and others in searching for these forms in different parts of the country. He will be pleased to determine specimens found under various conditions, make rearings therefrom if possible, and thus add to our knowledge of the subfamily Heteropezinæ, a group which should be fairly abundant in North America and one deserving careful study.

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SCIENTIFIC BOOKS

Minéralogie de la France et des ses colonies; description physique et chimiques des minéraux; étude des conditions géologiques de leurs gisements. Par A. LACROIX. Paris, Librairie Polytechnique, Baudry et Cie, éditeurs. 1893–1910. Four volumes. 8vo. Pp. xx + 723; 804; vi + 815; iii + 923.

This monumental work, which testifies at once to the untiring industry of the writer and to his thorough mastery of the material he has collected, is destined to rank as one of the most valuable contributions to the science of descriptive mineralogy. It consists of four large volumes, containing in all about 3,300 pages, and illustrated with more than a thousand figures, a large number of which are photographic reproductions of characteristic specimens. The first volume was issued in 1893, and at that time the author believed that the work would be completed in two years' time by the issue of a second volume;

but the material was so abundant that the issue of a third, and finally of a fourth volume became requisite.

In his preface to the first volume M. Lacroix calls attention to the fact that France has been commonly regarded as a land poor in minerals, and he finds an explanation of this belief in the comparatively slight favor that has been accorded to mineralogical studies there. A careful consideration of the geological features of that land, the great development attained there by the crystalline schists, by the ancient eruptive rocks, and by the later volcanic ones, should have served as proof that a great variety of mineral forms would be found. The author has sought in every case to trace the mineral to its original source and, as far as possible, to study the conditions controlling its production.

While it is essentially a treatise of descriptive mineralogy that M. Lacroix has produced, he has sought to give, in the case of each mineral, all the information necessary for the student regarding composition, optical properties and general characteristics, so that there might be no necessity to have recourse to other manuals. The crystallographic data are given both in the notation of Lévy-Des Cloizeaux and in that of Miller, and this greatly facilitates the use of the book for those unfamiliar with the French notation. The measurements given are all from specimens secured in the French deposits, the greater part of which have been collected by the author himself.

The considerable interval of time intervening between the issue of the second, third and fourth volumes, and the accumulation of new data—especially from Madagascar—that the author has collected during the past decade, renders the last volume a supplementary one; but the various new items are always referred to their proper place in the general scheme of the work.

The rich material has been arranged, in the main, according to the classification of Groth, and the full and accurate index renders it an easy matter to find the information given in regard to each mineral. The small percentage of mineral substances not included in the work are those which have not been found in France or in her colonies. The number of gem-stones—that is, of stones furnishing gem-material—is comparatively small, except in the case of the Madagascar deposits. Of the precious metals also there is no great abundance, in spite of the well-known fact that in Roman times the Gauls were exceptionally well supplied with gold. They appear to have nearly exhausted the deposits with which they were acquainted, and no new ones of equal value have since been discovered. In this connection, we may note (Vol. II., p. 422) an illustration figuring a gold medal struck in 1786, and made from the first ingot secured from the mine of La Gardette, dept. Isère.

The fourth volume is largely occupied with the treatment of the great variety of minerals found in the French colony of Madagascar, many of these having been collected by M. Lacroix in 1902 and 1903, when he was on an official mission to the island. More especially the pegmatite rocks of Mt. Bity and its neighborhood have yielded fine specimens of a great many types and varieties with which we are already familiar, and also some that are new or have not been met with in the same perfection elsewhere. Among these may be noted a new species, bityite, named by M. Lacroix, and the beautiful pink variety of beryl, which the writer of the present review has named morganite, in honor of our distinguished fellow-citizen, J. Pierpont Morgan. As the beginning of the systematic search for minerals in Madagascar is of such recent date, we may hope that the future has other pleasant surprises in store for us.

In the course of the publication of this work, begun eighteen years ago, the author was elected a member of the Académie des Sciences in Paris, an honor no one has better deserved than he. His single-hearted devotion to the progress of science is well shown in the following words prefixed to the last volume of his book: "I shall consider myself amply rewarded for my long task if this book should help to stimulate the study of the natural history of minerals in France."

It must be welcome news to the French that their recent acquisition, Madagascar, known as the "Grande Ile," contains many minerals valuable from a commercial point of view, and which may eventually serve to make some return to France for her immense expenditure of blood and treasure in establishing her dominion in that island. Very possibly similar investigations systematically conducted in parts of Cochin China and Tonquin would also reveal mineral deposits of value, not yet uncovered.

M. Lacroix, who was born in Mâcon, department Saône-et-Loire, February 4, 1863, was a pupil of F. Fouqué, of Des Cloizeaux and of Michel-Lévy, and has been since 1893 professor of mineralogy at the Muséum d'Histoire Naturelle, in Paris, an institution founded in 1793, during the French Revolution. Here the minerals contained in the Cabinet du Jardin du Roi, the greater part of which had been collected by D'Angiviller for Buffon, represent the nucleus of what has since become a most extensive and representative collection.

The following illustrious men have served as directors of the museum: Daubenton, 1793–1800; Dolomieu, 1800–1802; Hauy, 1802–1822; Alex. Brongniart, 1822–1847; Dufrenoy, 1847–1857; Delafosse, 1857–1876; Des Cloizeaux, 1876–1893; Lacroix, 1893 to the present time.

The important collections forming part of the great museum collection[1] are as follows: Collection de Chantilly (1793), Coll. Weiss (1802), Coll. Brongniart (1823), Cabinet de la Monnaie (Coll. Sage 1825), Coll. Gillet de Laumont, embracing the collection of Romé de l'Isle (1835), Coll. Haüy (1848), Coll. de l'Académie des Sciences (1855), Coll. Dusgate (1874), Coll. Bischoffsheim (1890). All of these, except that of Haüy and of M. Bischoffsheim, are in the general collection.

Besides his "Minéralogie de la France," M. Lacroix has published an exhaustive study of the intrusions in volcanic rocks, and, in collaboration with M. Michel-Lévy, a study of the minerals characteristic of different rocks.[2] In addition to these special works, no less than 260 articles and papers issued in various scientific journals bear witness to the great industry and to the many-sidedness of this writer.[3] There is no broader mineralogist in Europe; the range of his knowledge and the extent of his work in geology, petrography, chemistry and crystallography, and in the correlation of these sciences, constitute and prove a combination of gifts and acquirements rarely met with in one man.

The various scientific missions with whose execution M. Lacroix has been entrusted have led him to Great Britain, Scandinavia, Italy, Germany, Greece, Asia Minor and Madagascar, as well as to North America and the Antilles. After the dreadful eruption of Mt. Pelee, he was selected to head the scientific expedition to Martinique in 1902–3. These missions have afforded him exceptional opportunities for the study of the conditions under which mineral forms appear in many different parts of the world, of their associations and probable genesis. The wide experience thus acquired has undoubtedly contributed much to the special excellence of M. Lacroix's work in the field of mineralogy. Full appreciation has been accorded to him both in his native land and in foreign countries. He has twice been Lauréat de l'Institut, in 1892, and in 1903, and, as we have noted, was elected a member of the Académie des Sciences, section of mineralogy, in 1904.

He is an honorary or corresponding member of scientific societies in London, St. Petersburg, Vienna, Rome, Turin, Kristiania, etc., and is also an honorary member of our New York Academy of Sciences.

Eighteen names has Professor Lacroix added to mineralogy. They are as follows: Fouqueite (1889, *Bull. Soc. Min.*, XII., 330),

[1] "Collection de Minéralogie du Muséum d'Histoire Naturelle," Deuxième édition, Paris, 8vo, 1900, 112 pp., 1 pl.

[2] "Les enclaves des roches volcaniques," Mâcon, 1893, 770 pp. with 35 figures and 8 colored plates, 8vo. "Les minéraux des roches," Paris, 1888, 334 pp., 8vo.

[3] "Notes sur les Travaux Scientifiques de M. A. Lacroix, Prof. de Minéralogie du Muséum d'Histoire Naturelle," Paris, 1903, 4–126 pp.

michellevyte (1889, *Comptes Rendus,* CVIII., 1128; "Minér. de la France," IV., 48), morinite (1891, *Bull. Soc. Min.,* XIV., 187; "Minér. de la France," IV., 539) pseudoboleite (1895), gonnardite (1896, "Minér. de la France," II., 279), ktypeite (1898), picrocrichtonite (1900, "Minér. de la France," III., 284), pseudochalcedonite (1900, "Minér. de la France," III., 159), grandidierite (1902, "Minér. de la France," IV., 670), giorgiosite (1905), georgiadesite (1907), palmierite (1907), plancheite (1908, "Minér. de la France," IV., 757), villiaumite (1908, "Minér. de la France," IV., 881), bityite (1908, "Minér. de la France," IV., 673), metacristobalite (1909, "Minér. de la France," III., 806).

George F. Kunz

BOTANICAL NOTES

TWO NEW BOTANICAL JOURNALS

Within the past few months two new botanical journals have appeared in this country, asking for recognition and support by botanists.

The first in point of time is the *American Fern Journal,* the first number of which appeared about the middle of last August. It is now announced to be the "official organ of the American Fern Society," and its place of publication is Port Richmond, N. Y. It is to be "devoted to the general study of ferns," and is to appear quarterly. The field of the new journal appears to be distinctly systematic in the old sense, and would seem to be intended to serve old-time collectors of ferns, and the private makers of fern herbaria. While the *Fern Journal* does not cover exactly the field already occupied by the *Fern Bulletin,* published by W. N. Clute, the latter being much less technical, it must be confessed that they are rather too nearly alike, and one is led to wonder whether there is room in this country for two journals devoted to such a small group of plants as the ferns. However, we may hope that after a period characterized by a "struggle for existence" there may be a "survival of the fittest." In the meantime let us keep up our subscriptions for both periodicals, hoping that the best that there is in each may be preserved in the "survival," which may be a "Journal-Bulletin."

The other journal—*Phytopathology*—is also an "official organ," having for this relation the American Phytopathological Society. It "is designed primarily as a channel of publication for the phytopathological contributions of the members of the society." The principal editors are Professor L. R. Jones, of the University of Wisconsin, Dr. C. L. Shear, of the U. S. Department of Agriculture, and Professor H. H. Whetzel, of Cornell University. It is to appear bimonthly, and the subscription price is three dollars.

It is clearly to be a strictly scientific journal of plant pathology, having no popular leanings whatever. Its field has hitherto been wholly unoccupied, and there should be no question as to the support of the journal. It should be found on every botanist's table, and should be accessible to all students of plant pathology.

A PERIODICAL FOR MOSS STUDENTS

A new chapter is opened for *The Bryologist;* with the January, 1911, number it becomes the property of The Sullivant Moss Society, and its officers recently elected become the advisory board: President, Dr. Alexander W. Evans, Yale University; vice-president, Miss Caroline Coventry Haynes, Highlands, N. J.; secretary, Mr. N. L. T. Nelson, Des Moines College, Des Moines, Ia.; treasurer, Mrs. Annie Morrill Smith, Brooklyn, N. Y. They have appointed Dr. A. J. Grout, as editor-in-chief, with associate editors as follows: Dr. George N. Best, Rosemont, N. J.; Dr. A. W. Evans, New Haven, Conn.; John M. Holzinger, Winona, Minn., and Professor Lincoln W. Riddle, Wellesley College, Wellesley, Mass.

The Sullivant Moss Society has held seven most successful public meetings in affiliation with the American Association for the Advancement of Science, and plans to hold the eighth in the same connection at Washington, D. C., this coming December.

It will be noticed that the associate editors represent an eminent authority in the several

groups treated of in *The Bryologist,* namely, Dr. Best, the pleurocarpous mosses; Professor Holzinger, the acrocarpous mosses; Dr. Evans, the Hepaticae, and Professor Riddle, the lichens.

HOUGH'S LEAF-KEY TO THE TREES

MR. ROMEYN B. HOUGH has brought out a handy pocket manual which he calls a "Leaf Key to the Trees of the Northern States and Canada." The booklet is of such dimensions that it can be carried very easily in one's pocket, its dimensions being 4½ by 6 inches, and not over a quarter of an inch in thickness. In about thirty pages all of the common native trees from the Rocky Mountains eastward, and north of the latitude of North Carolina, are briefly characterized by means of keys which refer principally to their leaves. With this in hand the tyro ought to find no difficulty in finding the name of any native tree in the region named. It should be especially helpful to young foresters.

SHORT NOTES

A YEAR or so ago W. N. Clute brought out a little "Laboratory Botany" (Ginn) for use in high schools, which should have been noticed long ago. It has already commended itself to teachers as a most useful laboratory guide.

THE crown-gall of plants is discussed very fully and conclusively in Bulletin 213 of the Bureau of Plant Industry, of the United States Department of Agriculture. The authors, Erwin F. Smith, Nellie A. Brown and C. O. Townsend, find that *Bacterium tumefaciens* produces tumors upon many species of plants in widely separate parts of the natural system. Thus peach, apple, rose, quince, chestnut, grape, etc., when attacked by this organism develop the growths known by the name of "crown gall."

Parts III. and IV. of Oakes Ames's "Orchidaceae" continue to maintain the high standard set in the first and second parts. The books are not only of high scientific value to the botanist, but the printing and paper are superb, and when added to the wealth of artistic etchings constitute volumes that any artist might be glad to own. They form a notable addition to the literature of botany.

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SPECIAL ARTICLES

THE POISONOUS EFFECTS OF ALCOHOLIC BEVERAGES NOT PROPORTIONAL TO THEIR ALCOHOLIC CONTENTS

SUCH a vast amount of investigation and discussion has been centered on the liquor problem during the last few years that it seems almost presumptuous to attempt to add any new information to the subject or even to emphasize a point which has been previously recognized but not thoroughly appreciated.

In the report of the investigations made by the sub-committee of the committee of fifty to investigate the liquor problem, Abel[1] states "That more concentrated alcoholic liquors or spirits are, from a practical point of view, the most toxic of all alcoholic beverages. If whiskey or cognac were always to be diluted with water until the percentage of alcohol was brought down to ten per cent., they would be no more toxic than wine of the same strength."

These statements would lead one to infer that if the alcoholic content of all beverages was reduced to the same percentage the toxicity of each beverage would be the same. If true, such a conclusion would greatly simplify the method of determining the relative harmfulness of the many kinds of alcoholic beverages.

Numerous investigators have subjected various living organisms to the influence of pure ethyl alcohol diluted with water and also to beverages which contained varying amounts of it. In general they have obtained definite results showing that alcohol in appreciable quantities is always injurious to living matter.

It is recognized that some species of living organisms are more resistant to the influence of alcohol than others, and also that some individuals of the same species are more resistant than other individuals, but if many indi-

[1] "Physiological Aspects of the Liquor Problem," 1903. A report by the sub-committee of the Committee of Fifty to investigate the liquor problem, edited by John S. Billings, New York.

viduals of any species are subjected to the influence of alcohol it can be determined in general how great an amount of alcohol the species can endure.

In some experiments with rotifers, *Hydatina senta,* to determine the effect of different external influences upon the parent and offspring, various alcoholic beverages have been used and have given very definite results as to their relative toxicity. These experiments are not exhaustive nor complete, but it seems advisable to record them since they demonstrate very clearly that the toxic effect of some of the common alcoholic liquors is not proportional to the amount of alcohol contained in them.

The rotifers are microscopic aquatic animals living in certain kinds of foul water. In the laboratory such water was prepared by placing a small amount of horse manure in a two-quart jar of tap water. This mixture was inoculated with various kinds of bacteria and also with very small flagellated protozoa. In about thirty-six hours the jar was swarming with millions of the small protozoa. A cubic centimeter of this water containing the protozoa was added to nine cubic centimeters of tap water and then adult rotifers were placed in this mixture. They lived in it readily eating the protozoa and laying eggs which developed into mature offspring in about forty-eight hours.

Varying amounts of each alcoholic beverage were added to this water in which the rotifers lived thus causing the toxicity of the whole solution to vary according to the amount of the alcoholic beverage present in the mixture. As an indicator to the toxicity of the beverages thus diluted with the water in which the rotifers lived, two points were noted: (1) the percentage of alcohol present in the diluted beverage at which the animals died within 10–30 minutes; (2) the highest percentage of alcohol present in the diluted beverage at which the females produced apparently normal young.

The following tables give the details of the experiments and bring out clearly the fact that alcohol is not the only cause of the injurious effects produced by alcohol beverages.

If two beverages which contain approximately the same amount of alcohol are compared the poisonous effects of each are sometimes nearly equal as is true of claret and white wine or Holland gin and brandy, but, in other cases, the poisonous effects may be very unequal, as is very clearly shown in the comparison of the second sample of cider and Ballentine's ale. Here the alcoholic contents of each are nearly equivalent but the toxicity of the cider far surpasses that of the ale in both sets of experiments as recorded in Tables I. and II.

TABLE I

Showing the Highest Percentage of Alcohol in the Beverages at which the Rotifers Lived 10–30 Minutes

Beverages	Per Cent. Alcohol by Volume in Original Sample	Per Cent. Alcohol in Diluted Portion of Sample Used	Duration of Life of Rotifers	No. of Individuals Used
Cider	7.5	0.2	25 minutes	10
Cider	6.23	0.4	22–40 "	30
Cider	8.8	0.4	30 "	10
Claret	11.	0.4	30–45 "	50
Claret	9.25	0.5	20 "	20
Port wine	19.65	0.9	30 "	10
Port wine	22.6	1.5	30 "	40
White wine	11.5	0.6	30 "	10
Sherry	20.5	1.5	30 "	40
Sherry	19.25	1.5	30 "	30
Dark beer	5.8	2.	30 "	10
Red star lager beer	3.75	2.	20 "	10
Schlitz beer	5.35	2.	20 "	10
Budweiser lager beer	4.9	2.	20 "	10
Ballentine's ale	6.3	2.	20–35 "	40
Ballentine's ale	6.3	2.	20–35 "	40
Bass's pale ale	9.25	1.	35 "	10
Bass's pale ale	8.5	1.5	15 "	10
Rye whiskey	46.4	10.	10 "	20
Blend whiskey	44.5	10.	60 "	20
Holland gin	49.	10.	35 "	20
Holland gin	52.	10.	35 "	20
French brandy	50.8	10.	20 "	30
Cooking brandy	53.2	10.	25 "	30
Absolute alcohol	99.5	10.	45–60 "	50

Liquors which contain a high percentage of alcohol may be more toxic or may be less toxic than liquors containing a low percentage of alcohol. Sherry and port wine which contain about twenty parts of alcohol are much more toxic than Schlitz's beer and Ballentine's ale,

both of which contain less than seven parts of alcohol. On the other hand, Holland gin, which contains approximately fifty parts of alcohol is much less toxic than any of the beers or wines which range in their contents from three to twenty-three parts of alcohol. Thus it seems that the total poisonous effects of alcoholic beverages are not entirely caused by alcohol but are due in part to other substances.

TABLE II

Showing the Highest Percentage of Alcohol in the Beverages at which Apparently Normal Young were Produced

Beverages	Per Cent. Alcohol by Volume in Original Sample	Highest Per Cent. Alcohol in Diluted Portion of Sample in which Young were Produced	No. of Females Producing Young
Cider	7.5	.065	10
Cider	6.23	0.1	30
Cider	8.8	0.1	5
Claret	11.	0.3	26
Claret	9.25	0.3	6
Port wine	19.65	0.3	10
Port wine	22.6	0.2	15
White wine	11.5	0.4	10
Sherry	20.5	0.9	14
Sherry	19.25	0.9	10
Dark beer	5.8	1.	5
Red star lager beer	3.75	0.6	6
Budweiser lager beer	4.9	0.3	20
Schlitz beer	5.35	1.	10
Bass's pale ale	9.25	0.05	10
Bass's pale ale	8.5	0.06	10
Ballentine's ale	6.3	1.	15
Ballentine's ale	6.3	1.	15
Rye whiskey	46.4	2.	10
Blend whiskey	44.5	2.	10
Holland gin	49.	2.	20
Holland gin	52.	2.	20
French brandy	50.8	2.	20
Cooking brandy	53.2	2.	30
Absolute alcohol	99.5	3.–4	50

In further support of this statement a few additional experiments of a somewhat different nature were made. A certain quantity of both claret and sherry were placed upon a steam radiator and allowed to evaporate. In both cases a residue remained. As soon as this residue was thoroughly dried distilled water was added until the original volume was restored. Then each solution was diluted in the same manner as the liquors which contained alcohol. Rotifers were placed in various dilutions of these solutions and the results compared with those obtained from the liquors containing alcohol.

TABLE III

Showing the Comparative Acute Toxicity of Claret and Sherry with and without Alcohol

Beverage	Alcohol in Diluted Portion of Beverage Used	Duration of Life of Rotifers	Alcoholless Liquor Diluted in same Proportion as the Alcoholic Liquor	Duration of Life of Rotifers	No. of Individuals used in each Experiment
Claret	1%	8–10 min.	1%	30 min.	40
Sherry	2%	15 min.	2%	60 min.	40

TABLE IV

Showing the Comparative Toxicity of Claret and Sherry with and without Alcohol in Dilutions of which Young Rotifers were Produced

Beverages	Highest Per Cent. Alcohol in Diluted Liquor in which Young were Produced	Highest Per Cent. Alcoholless Liquor in which Young were Produced. Diluted in same Manner as the Alcoholic Liquor	No. of Individual used in each Experiment
Claret	0.3	0.7	25
Sherry	0.9	1.5	25

The acute toxicity of claret and sherry which have the alcohol removed is much less than in the cases where the alcohol is present. Even with the alcohol removed claret is much more toxic than the alcoholless sherry and each of them is more toxic than absolute alcohol. The same fact is shown in the experiments where young rotifers were produced as is indicated in Table IV.

If alcohol is the only toxic ingredient of claret and sherry neither of them ought to produce poisonous effects upon rotifers after the alcohol is removed. These experiments, however, show that these two liquors are very toxic even when they contain no alcohol.

Tables I. and II. show that the wines are strikingly more toxic than the same percentage of absolute alcohol. Chittenden' found that wines had a greater inhibitory action on salivary and pancreatic digestion than did a cor-

responding percentage of absolute alcohol. This he states is due to their acid properties.

Malt beverages, as ales and beers, he states, also have a retarding influence on salivary and pancreatic digestion due to their acidity but it is less marked than it is in the wines. Both of the above tables show that some of the ales and beers are decidedly less toxic than the wines. Some of them, however, were as poisonous as the wines in the experiments where young were produced, but in the 10–30 minutes experiment on acute toxicity only Bass's ale equaled the toxicity of any of the wines. Its toxicity was the highest of all the malt beverages but it did not exceed the lowest toxicity of the wines.

The distilled beverages, whiskey, gin and brandy, were conspicuously less poisonous in both sets of experiments than either the wines or malt beverages. This is probably due to the fact that in the distilling process of their manufacture the volatile substances are separated from the non-volatile and perhaps toxic materials and are subsequently used in the making of the liquors. These distilled liquors approached the point of toxicity of absolute alcohol which was the least poisonous of all the alcoholic solutions used. Because of its purity it served as a control with which all the other beverages can be compared.

In a comparison it is readily seen that the wines are the most toxic, the malt liquors stand second in point of toxicity, and lastly the distilled liquors are the least toxic of all the beverages and approach nearest to the toxicity of absolute alcohol.

The value of these experiments is to show again that in the three main kinds of alcoholic beverages there are other important toxic ingredients than ethyl alcohol and also to demonstrate that the various alcoholic liquors when reduced to the same percentage of alcohol differ widely in their point of toxicity.

The results perhaps explain why different alcoholic beverages have such different effects upon the drunkard even though an equal intoxication is produced. It is generally recognized that brandy produces a certain type of drunkenness and that cider produces another type differing widely from the brandy type. Many of the other liquors also produce a particular type of drunkenness the characteristics of which are typical for each liquor. These types of drunkenness are doubtless partly caused, at least, by the non-alcoholic ingredients in the liquors.

D. D. Whitney

Wesleyan University,
Middletown, Conn.,
February 28, 1911

BIOLOGICAL SOCIETY OF THE PACIFIC COAST

The first meeting of a new society for Pacific coast biologists was held on April 1 at Berkeley, California. An afternoon meeting, at which papers were presented by President Jordan and Professor Zinsser, of Stanford University, and Professors Kofoid and Maxwell, of the University of California, was followed by a dinner at the Hotel Shattuck, and by participation, in the evening, in a joint general public meeting of the newly organized Pacific Coast Association of Scientific Societies. At this meeting addresses were made by Presidents Wheeler and Jordan, of California and Stanford universities, Professor Kellogg, of Stanford University, and Mr. George Dickie, marine engineer, of San Francisco.

The Biological Society of the Pacific Coast begins with an active membership of seventy, representing California, Washington, Oregon, Arizona and Utah. Three meetings will be held each college year, of which one will be known as the annual meeting and will be held in conjunction with the meetings of the various other societies composing the Pacific Coast Association of Scientific Societies. The officers of the society for 1911–12 are: Professor Vernon L. Kellogg, president; Professor H. B. Torrey, secretary-treasurer, and Professor H. J. Maxwell, third member of the executive committee.

SOCIETIES AND ACADEMIES

THE HELMINTHOLOGICAL SOCIETY OF WASHINGTON

The fourth regular meeting of the society was held at Dr. Stiles's residence on February 9, 1911, Dr. Stiles acting as host and Dr. Pfender as chairman.

Mr. Foster presented a note on a nematode from the stomach of the pig. This form had been provisionally identified as *Spiroptera strongylina*,

but the location of the vulva in the anterior portion of the body indicates that it is a new species or else that the available descriptions of the European *S. strongylina* are in error in describing the vulva as near the anus. *Spiroptera strongylina* has been reported from Texas in 1892 by Francis, who states that this species is common there but that the identification is doubtful, and from Kansas in 1910 by Kaupp, who figures the vulva as posterior. He may have so figured it as the result of an error of interpretation. Specimens in the helminthological collection of the Bureau of Animal Industry were collected by Kilborne as early as 1884. These specimens show the vulva in the anterior portion of the body. The European species is usually described as having a smooth mouth, though von Linstow notes six round papillæ. The American species has two lips and six long papillæ. There are other differences in the ratio of the length of the large and small spicules.

The worm occurs half buried in the mucosa of the stomach and is therefore a dangerous parasite. Von Ratz in 1897 reported an epizootic due to *Spiroptera strongylina,* in which a number of pigs were seriously affected and some killed. The parasite caused sloughing of the gastric mucosa and it is probable that the American species does the same. It is therefore of some economic importance.

Associated with the American *Spiroptera* were specimens of *Physocephalus sexalatus,* recorded here for the first time from the United States. This is also the first record of its occurrence in the domestic pig. Former records are from the peccary and the wild boar.

Dr. Goldberger presented a note on some trematodes of fish. The œsophagus presents a notable peculiarity. It is ordinarily described as ending at the fork where the intestinal ceca begin. In some forms there is said to be no œsophagus present. This statement is due to a failure to take into account a structure that is a part of the ceca though it really belongs to the œsophagus. This structure is limited posteriorly by a constriction or sphincter, and is really a forked œsophagus, extending from the pharynx to this constriction. This structure he has noted in the genus *Azygia* and in *Leuceruthrus.*

Dr. Goldberger also presented a note on a trematode from a black snake. In this trematode (*Styphlodora bascaniensis*) Laurer's canal does not go to the dorsum and open to the exterior, but ends in a globular swelling containing cells like vitelline cells and some other structures interpreted as spermatozoa. The worm has a well developed sperm receptacle. *Aspidogaster conchicola* has been described as having a similar form of Laurer's canal.

In discussing Dr. Goldberger's paper, Dr. Stiles called attention to the fact that in 1894 he had stated in a paper on *Fasciola magna* that the egg shell was probably formed by the vitellogene glands rather than by the so-called shell glands. A paper by Goldschmidt in 1909 has given in detail the formation of the egg shell, his conclusions being somewhat similar to those of Stiles in 1894. Dr. Ransom stated that he had come to the same conclusion regarding the shell gland of certain bird tapeworms. He had thought that possibly the walls of the uterus were partly responsible for shell formation as shells were found only after the eggs had been in the uterus for some time.

Mr. Hall presented a paper entitled "The Need and Desirability of a Biological Survey of the Parasite Fauna of the United States." The amount of data relative to the occurrence, distribution, habits and importance of the animal parasites of the United States is very small. There are few persons who collect material or contribute notes in this field of investigation. The large amount of material in the government laboratories at Washington has been largely collected at Washington and at the slaughter-houses at big packing centers, and in these cases there is often little data as to the localities where infections were acquired.

As a preliminary to a biological survey of our parasite fauna, statements as to the occurrence and distribution of our more important parasites, so far as the occurrence and distribution is known, should be made. Such a statement would furnish incentive for additional records, as it is easier to refer to such a record and add to it than to look through our present scattered records, many of which are not available to most persons. Conversely, such a record would serve as a guide in looking for parasites. As an illustration of the utility of such a survey, it may be noted that the preliminary work on the hookworm made it possible for physicians to add intelligently to the records, thus mapping out the infected areas. Conversely, it led physicians to look for the hookworm in those states from which it was recorded or where the records indicated that it would be found, for such records indicate possibilities and probabilities in addition to showing known facts.

Such records indicate foci of infection and awaken the interest of persons resident at such foci. They are essential in campaigns of eradication. A study of the distribution, habits and importance of some of our animal parasites may throw light on life histories by indicating a corresponding distribution of intermediate hosts or of other conditions requisite for the life cycle. This would permit of outlining more adequate means of prophylaxis, would make possible more intelligent estimates of the economic importance of our parasites, and would aid in guarding against indigenous and imported species. With such preliminary compilations of records as a nucleus, it should be possible in time to proceed to a real biological survey of our parasite fauna.

Dr. Ransom presented a note on the viability of nematode eggs and larvæ. In some species there is a great difference between the viability of eggs or newly hatched embryos and that of the full-grown larvæ. The first two are quickly killed by low temperatures or drying, but the ensheathed larvæ can be frozen for some time, or frozen and thawed alternately without damage. Of two cultures of ensheathed larvæ, one of which was kept out of doors during the winter and the other indoors, the former was found in the better condition at the end of the winter. The probable explanation is that low temperature inhibits activity and in this way conserves the food supply stored up in the intestinal cells of the larvæ. The ensheathed larvæ can also be dried for some time and then revived by the addition of moisture.

Nematodirus filicollis develops to the ensheathed stage before hatching, a period of about a month being required for the development at a temperature of about 70° Fahrenheit, whereas under similar conditions the stomach worm (*Hæmonchus contortus*) hatches in about two days, and does not develop to the ensheathed stage until after hatching. The eggs of *Nematodirus* are much more resistant to low temperatures than those of the stomach worm. A temperature of 12° Fahrenheit was found to kill eggs of the stomach worm in seven to ten days, while eggs of *Nematodirus* were viable at the end of eight weeks after exposure to the same temperature. At 32° to 40°, eggs of the stomach worm were still alive at the end of eight weeks, but were dead after thirteen weeks. The eggs and embryos of *Strongyloides* do not resist drying. In this genus the embryos do not ensheath.

Dr. Stiles presented a note on the progress of the hookworm work in this country, and noted the finding by Stiles and Miller, on the basis of microscopic diagnosis, of cases of hookworm disease in Kentucky. He exhibited maps showing all the counties known to be infected.

Maurice C. Hall,
Secretary

The Anthropological Society of Washington

The 453d regular meeting of the society was held in the hall of the Public Library, March 28, 1911, 8:00 P.M., with Mr. George R. Stetson, vice-president of the society, in the chair.

Professor R. B. Dixon, of Harvard University, read a paper on "Polynesian Mythology." After a geographical survey of the islands of the Pacific, including Polynesia, Melanesia, Micronesia and Malasia, the speaker gave a delineation of the pantheon and a concise exposition of the theology entertained, with greater or lesser variations, by the different tribes of these islands. The gods are broadly divided into greater and lesser ones. In addition to these there are ancestral and totemic deities. The four great gods are: Tane (dialectically, Kane), Tu (Ku), Tangaroa (Tanaloa) and Rongo (Lono, also Oro). The lesser gods are for the most part considered as their offspring. Of the four great gods Tane is the greatest. He is conceived as self-evolved, existing from eternity, the father of men, and is connected with the sky. He is supreme in the Hawaiian Islands and New Zealand, although he had there no temples and scarcely received any worship, while in Samoa and central Polynesia at large he is almost unknown. The same is the case with Rongo, the god of agriculture, and Tu, the god of war. On the other hand, Tangaroa, who forms a group by himself, enjoyed great honor in Samoa and the central portion of Polynesia, but was associated with darkness and evil in Hawaii and seems to be a late comer into Hawaii, imported from Tahiti or the Marquesas Islands. There are, as a rule, no images made of the great gods. The only representations made of them are stone pillars or wooden poles swathed in tappa or mats. The mythology of the other islands of the Pacific Ocean, as that of Melanesia, Micronesia, agrees in some portions with that of Hawaii and New Zealand, in others with that of Samoa and central Polynesia.

The paper was discussed and commented upon by many of those present.

I. M. Casanowicz,
Secretary